BOEING

Volume 2
Final Report
Mission Analysis
D180-27477-2

2

Space Station Needs, Attributes, and Architectural Options Study

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RESEARCH INSTITUTE OF MICHIGAN
INTERMETRICS
Microgravity Research Associates, Inc.
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Space Station
Needs, Attributes and Architectural Options Study

Contract NASW-3680

D180-27477-2

Final Report

Volume 2

Mission Analysis

April 21, 1983

for

National Aeronautics and Space Administration

Headquarters

Washington, D. C.

Approved by Gordon Woodcock

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FOREWORD

The Space Station Needs, Attributes and Architectural Options Study (Contract NASW-3680) was initiated in August of 1982 and completed in April of 1983. This was one of eight parallel studies conducted by aerospace contractors for NASA Headquarters. The Contracting Officer's Representative and Study Technical Manager was Brian Pritchard. The Boeing study manager was Gordon R. Woodcock.

The study was conducted by Boeing Aerospace Company and its team of subcontractors:

Arthur D. Little, Inc. (ADL)	Materials Processing in Space
Battelle Columbus Laboratories	Materials Processing in Space
ECON, Inc.	Pricing Policies and Economic Benefits
Environmental Research Institute of Michigan (ERIM)	Earth Observation Missions
Hamilton Standard	Environmental Control and Life Support Equipment
Intermetrics, Inc.	Software
Life Systems, Inc. (LSI)	Environmental Control and Life Support Equipment
Microgravity Research Associates (MRA)	Materials Processing in Space
National Behavioral Systems (NBS)	Crew Accommodations and Architectural Influences
RCA Astro-Electronics	Communications Spacecraft
Science Applications, Inc. (SAI)	Space Science

This document is one of seven final report documents:

D180-27477-1	Volume 1, Executive Summary
D180-27477-2	Volume 2, Mission Analysis
D180-27477-3	Volume 3, Requirements
D180-27477-4	Volume 4, Architectural Options, Subsystems, Technology, and Programmatics
D180-27477-5-1	Volume 5-1, National Defense Missions and Space Station Architectural Options Final Report (SECRET)
D180-27477-5-2	Volume 5-2, National Defense Missions and Space Station Architectural Options, Final Briefing (SECRET)
D180-27477-6	Volume 6, Final Briefing

D180-27477-7-1	Volume 7-1, Science and Applications Missions Data Book
D180-27477-7-2	Volume 7-2, Commerical Missions Data Book
D180-27477-7-3	Volume 7-3, Technology Demonstration Missions Data Book
D180-27477-7-4	Volume 7-4, Architectural Options, Technology, and Programmatics Data Book
D180-27477-7-5	Volume 7-5, Mission Analysis Data Book

Note: The volume 7 data books will be distributed to a limited number of requestors.

The study task descriptions and a final report typical cross reference guide are found in Appendix 1.

The Boeing and subcontractor team member are listed in Appendix 2.

Acronyms and abbreviations are listed in Appendix 3.

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1.0 INTRODUCTION

1.1 OVERVIEW

This document gives the results of the space station user mission analyses that were conducted during this study (with the exception of the classified national security missions, which are reported in Volume 5 of this final report series). As this volume presents summaries of the results of these mission analyses, the reader will be directed where necessary to more detailed discussions and data in one of the Volume 7 Data Books.

In the remainder of this Introduction, the background, objectives, ground rules and guidelines of this mission analysis activity will be discussed. In section 2.0, the approach used to accomplish the objectives is described.

Section 3.0 contains the results of the various mission analyses. Section 3.1 discusses the science and applications missions (solar physics, space science, astrophysics, earth observation, life sciences, and materials sciences). Section 3.2 contains the results of the commercial missions analyses (materials processing, communications satellites, and Earth observation). Section 3.3 discusses the technology development missions. The space operators missions (construction, satellite servicing, and flight support) are discussed in Section 3.4.

In Section 4.0, time-phased scenarios of operational capabilities are described.

The integrated requirements derived from these mission analyses results are given in Section 5.0. These requirements are categorized for the high and low inclination manned space stations and for a scenario with no space station.

In Section 6.0, the results of the benefits analysis are given.

1.2 BACKGROUND

During the late 1970's/early 1980's, as the shuttle transportation system became an operational reality, NASA was studying what the next logical step would be in space technology. The principal contenders were an unmanned space platform and a manned space station.

The unmanned space platform was investigated by a series of contracted studies sponsored by the Marshall Space Flight Center during the 1980-82 time frame under the name of Science and Applications Space Platform (SASP). The manned space station concept was investigated by contractual studies sponsored by the Johnson Space Center during the same time period under the name of the Space Operations Center (SOC). The SASP concept was subsequently extrapolated to include a manned version, the Science and Applications Manned Space Platform (SAMSP).

The next step was taken in 1982, when NASA-Headquarters convened a Space Station Task Force with personnel from several field centers to develop mission and system requirements, system definition and program planning for a space station system. Eight aerospace contractors were awarded parallel contracts to explore the potential space station mission needs, attributes, and architectural options. A Mission Requirements Working Group (MRWG) was formed to integrate and analyze the mission requirements that were produced during this study.

1.3 OBJECTIVES

The objectives of the mission analysis portion of this study were the following:

1. Describe the mission opportunities, identified as desirable by the broad user community, that could benefit from a space station system during the 1990-2000 time period.

2. Define the time-phased requirements imposed by these missions on the Space Station System.

3. Refine and integrate these mission opportunities and requirements into fiscally responsible time-phased mission models.

4. Define the economic benefits that would be obtained by accommodating the mission opportunities with the Space Station System.

Through this effort, NASA expects to obtain the necessary data for reaching a decision to create a national facility, believed to be a logical and necessary next step in the achievement of this nation's space policy.

1.4 GROUND RULES AND GUIDELINES

The following basic ground rules and guidelines, given by NASA, were used in the performance of this study:

- The permanent facilities will be Shuttle launched and Shuttle tended, as required. The Space Shuttle User's Handbook was used to provide the associated guidelines.
- Potential missions of interest included domestic and foreign science, applications and commercial users as well as U.S. national security and space operations missions.
- Time period of interest was 1990 through the year 2005.
- Missions identified and included in the study results have identified users, and include the specific source of user input.
- Although the study primarily considered the requirements for a permanent manned space stations in low Earth orbit, requirements for the full range of potential future support systems were also established.
- The Tracking and Data Relay Satellite System (TDRSS) was the primary space-to-ground RF communications interface for space station operations. The TDRSS User's Guide was used to define the space stations interfaces.
- Development of space station attributes and architectural options considered the accommodation of all feasible missions with a single space station in the 1990 time frame. The evolutionary growth of the system required consideration of multiple space facilities.
- Applicable data and results from prior and current projects and studies were used.
- NASA provided the results of mission analysis studies conducted in other countries which are relevant to space station requirements as they become available.

1.5 ASSUMED SPACE STATION SYSTEM MISSION SUPPORT CAPABILITIES

Based on previous space station studies, including the recent SOC and SAMSP studies, there were a set of space station system mission support capabilities that were assumed potentially available for use in the missions analysis. Cognizance of these assumed capabilities was a necessary ingredient for the mission analysts in formulating the mission descriptions. The specific parameters associated with these capabilities were to be derived from the integration of the results of this mission analysis study. The following paragraphs detail these assumed capabilities.

Payload/Satellite Checkout and Servicing—It was assumed that the space station could provide a location for temporarily storing an Orbiter-delivered payload/satellite. The manipulation of the payload/satellite will be provided by a space station manipulator system. Holding fixtures will be available. The space station could also provide an umbilical system for providing facility power and control signals. The specific mix of space station supplied utilities and spacecraft supplied utilities were to be derived by analysis.

Payload/Satellite Assembly—The space station could provide necessary fixtures, manipulators, crew skills, and utility services necessary to assemble large payloads/satellites. The specific characteristics of this equipment were to be defined by analysis.

Upper Stage Support—The space station could provide the capability for storing, checking out, payload-to-vehicle mating, and launching of upper stage vehicles. The specific vehicle and the specific characteristics of these support capabilities were to be defined by analysis.

Teleoperator Vehicle Support—The space station could provide the necessary interfaces for one or more teleoperator maneuvering system (TMS) vehicles that would be stationed at the space station. The specific characteristics of this TMS interface were to be defined by analysis.

Support for Proximity Free-Flying Satellites—The space station could provide the necessary command and control of proximity free-flying satellites that will be formation flying with the space station. The specifics were to be derived by analysis.

Laboratory Support—The space station could incorporate provisions for one or more laboratories. Whether these are a dedicated or general purpose facilities was to be defined. The

laboratory support will include volume, utilities, data management, communications, and crew skills. The specifics were to be derived by analysis.

Attached Payload Support—The space station could provide the capability to attach payloads. This will include provisions for pressurized mission modules as well as unpressurized payloads. The support provisions will include structural attachment, utilities, crew skills, and environmental control (where necessary). The specifics were to be defined by analysis.

Maintenance—The space station could provide general purpose equipment and crew skills for maintenance of attached payloads.

Resupply—The space station's Logistics Module will be the primary mode for resupply of a mission. If the mission requires resupply beyond the capabilities of this Logistics Module, the mission shall provide its own resupply module.

Satellite Servicing—The space station could provide the necessary capabilities for servicing formation-flying satellites in situ or for retrieving the satellite for servicing on-board the space stations. The specifics were to be defined by analysis.

EVA Support—The space station could provide EVA as a routine mode of operation available to any on-board mission.

2.0 MISSION ANALYSIS APPROACH

We employed a structured, multistep procedure to get from user needs to space station mission requirements. A part of this procedure was automated to speed up the analysis. In this section of the report we present a summary of the procedure as an orientation prior to describing the results of our user mission needs investigations.

Our Approach to the mission analysis task is summarized in Figure 2.1-1.

2.1 MISSION IDENTIFICATION

Figure 2.1-2 shows the mission analysis team organization. This shows that a Mission investigator (MI) was appointed for each of the mission types. In most cases, each MI was assigned a supporting team of Boeing and/or subcontractor personnel. The MIs were to be advocates for their particular mission areas.

The specific mission identification approaches used by the Mission Investigators varied. Those approaches are described in detail in Section 3.0. In general, the approach was to contact as many potential users as possible--mostly by telephone contact but in some cases by personal visits. We found that mailing questionnaires to potential users was a fruitless endeavor. Mission subcontractors were hired so that we could obtain in-depth analysis of specific mission opportunities (e.g., communications satellites and semi-conductors). The analysts also combed the literature, including mission analyses conducted for the SOC and SASP studies and other relevant NASA data. Boeing and subcontractor personnel outside of the study team were frequently consulted for expert advise and supplemental data. The mission opportunities identified by this process were tabulated and catalogued on the NASA-supplied mission data forms. Over 500 potential missions were identified.

Each of the MI's and his team used a variety of criteria to screen the list of potential missions into a set of "reasonable" missions. Some mission ideas were discarded because of their lack of definition or lack of a clear-cut purpose. Many of the mission ideas were duplications. For example, some of the technology development missions were identical to proposed materials processing development missions. Other potential missions were set aside when it became apparent that they could more readily be accomplished using the shuttle only. Finally, some of the proposed mission concepts were discarded due to unreasonable or unsafe demands placed on the space station. An example was a mission that

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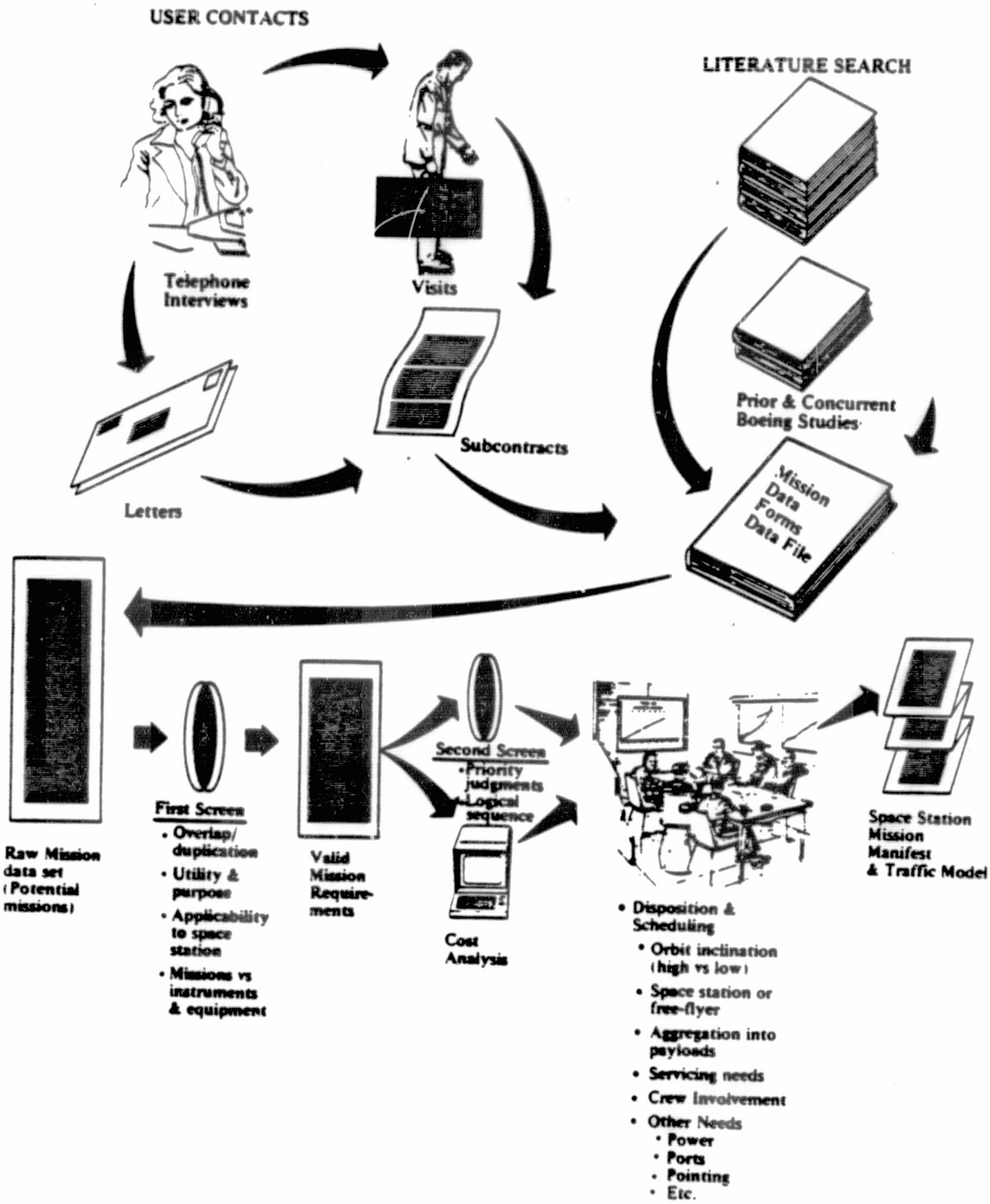

Figure 2.1-1: Mission Analysis Approach Overview

called for fabrication of lightweight cryogenic heat pipes. The application of this "reasonableness filter" pared the list of potential missions down to approximately 200 "valid missions". The rationale used by each MI is given in the Section 3.0 subsections.

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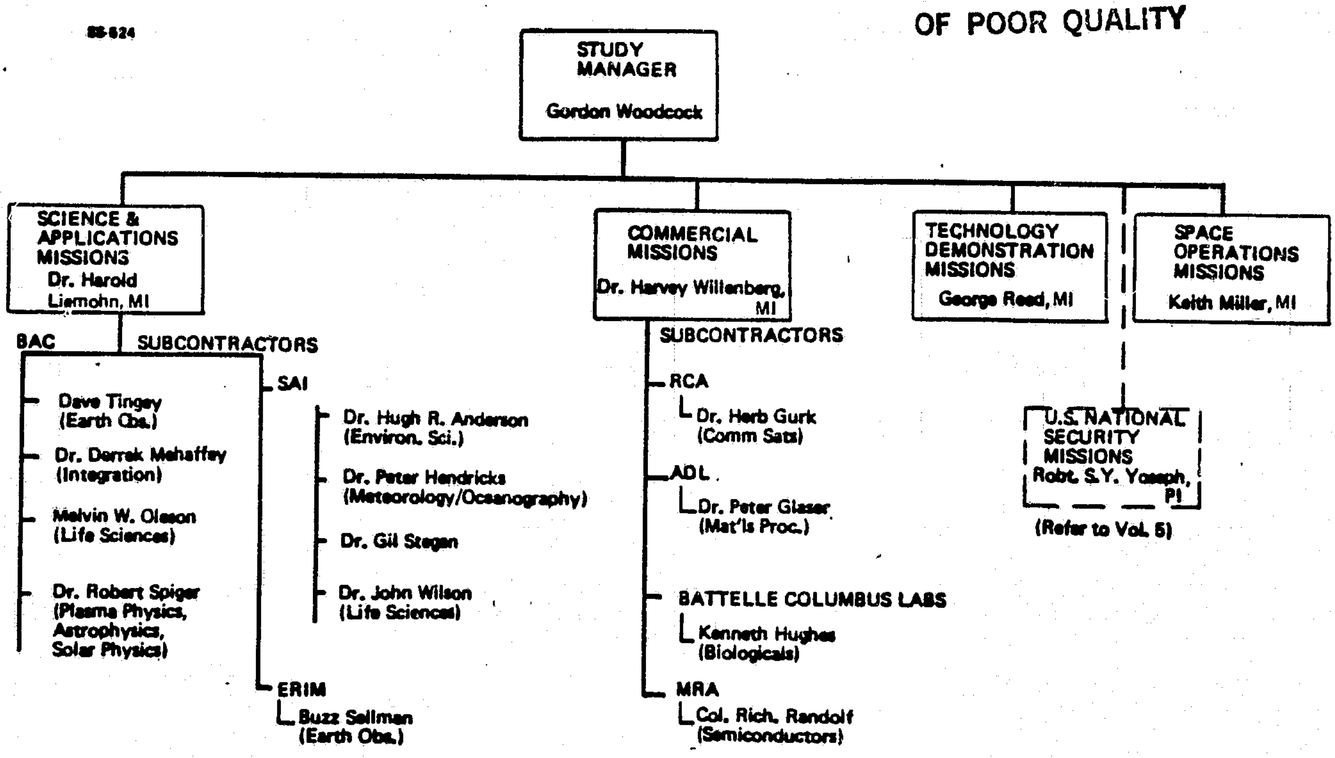

Figure 2.1-2. Mission Analysis Study Team

The next step was to screen these "valid missions". The rationale used by each MI is given in the Section 3.0 subsections.

The next step was to screen these "valid missions" again using cost and priority criteria. Each mission concept was priced. The aggregate time-phased costs of the various mission classes were compared to realistic estimates of the future funding capability of the institution that would be paying for the missions. In every case, the time-phased costs of the mission opportunities exceeded the available budget. The mission analysts then prioritized and rescheduled missions until the appetites fit within the budget. In some cases, the "valid mission", identified in the preceding step, had to be rescheduled beyond the year 2005 to fit within the funding constraints and were, subsequently, discarded because they fell beyond the scope of the mission analysis time window. Again, the specifics of this second screening process are discussed in the Section 3.0 subsections.

In parallel with the mission screening process, some of the missions, but not all of them, were analyzed in detail to establish potential payload configurations. The associated payload mission operations were then analyzed in detail to derive support equipment, crew skills, timelines, and space station accommodation requirements. The results of these sample analyses were then extrapolated and applied to other missions. These results were

factored into the cost analyses discussed in the preceding paragraph.

Our automated manifesting and space station accommodations analysis procedure, described below, recognized the intimate relationship between space transportation operations and space station operations. For this reason, individual missions as identified by the user needs analyses were combined into logical groups that represent reasonable space transportation and space station payloads.

This aggregation process, together with deletion of some missions by the screening process, created 46 STS/space station mission payloads from an input mission set of some 300 missions.

We identified certain missions that place a demand on space station services, but little or no demand on STS services. To account for these, we established a mission category designated as "carry-on", implying that the mission equipment could be carried in the shuttle mid-deck and brought aboard the space station by the arriving crew. Once on board the space station, a carry-on mission requires a certain amount of crew attention and other space station services.

There are at least three ways of counting missions for a space station. If one counts the number of discrete types of manifestable payloads, the result appears to be on the order of fifty. If one counts missions as defined by potential users, the result is a few hundred. One can obtain a still larger mission by counting each mission each time it flies, a figure on the order of a thousand.

2.2 AUTOMATED MISSION ANALYSIS SOFTWARE SYSTEM

The selected time-phased mission set was then input into our automated manifesting and accommodations analysis expert software system. Figure 2.1-3 illustrates the top-level software functions.

2.2.1 Input Data

The mission analysis software operates from two sets of input data: 1) Payload description data, and 2) the traffic model.

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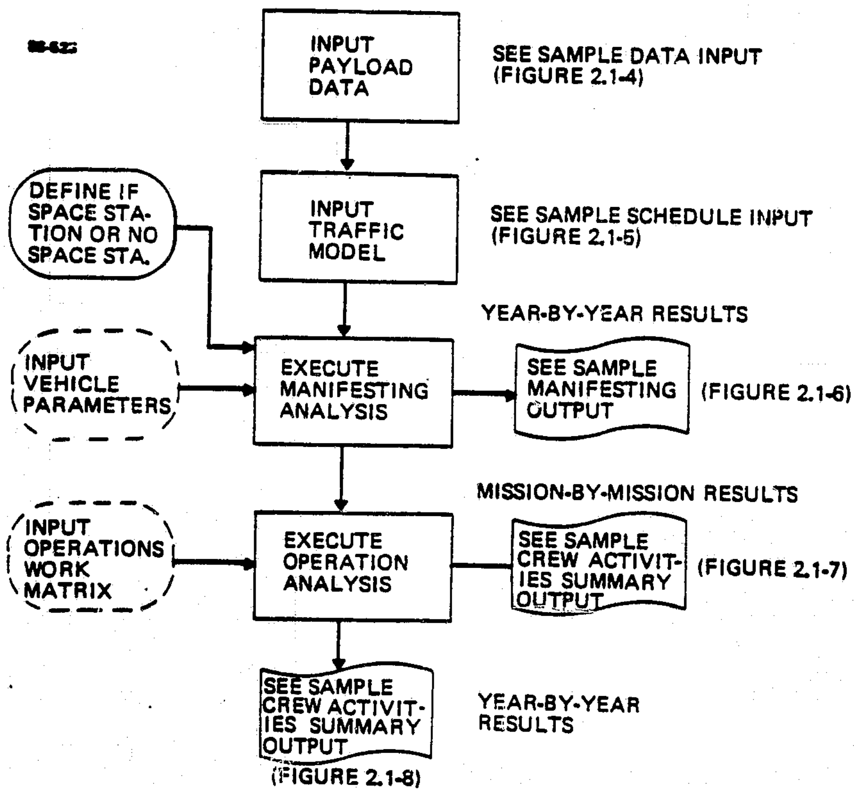

Figure 2.1-3. Automated Manifesting and Operations Analysis Software Functions

2.2.1.1 Payload Description Data

Figure 2.1-4 shows an example of the payload description data input format. Table 2.1-1 describes each of the parameters. This data was obtained from the mission data forms prepared by the analysts. The payload traceability matrix, Table 2.1-2, is used to track the payload data back to its source.

2.2.1.2 Traffic Model

Figure 2.1-5 shows an example of the traffic model input. Each payload was scheduled as to the year flown and the number of times flown during each year, if any.

2.2.2 Manifesting Analysis

The manifesting analysis software operates on the input data described above using some internal manifesting rules and parameters.

NO.	CODE	NAME	ORBIT ALT	ORBIT INCL	DELTA V'S UP	DELTA V'S DOWN	DELTA V'S D/O	PASSES PAYLD	PASSES SLPT	PASSES RET	LENGTHS PAYLD	LENGTHS SLPT.	PAYLD DIA	POWER KW	INTER VEHICLE	RNDZ DESTR	OPS CODE	POINTING DIR	LP/CA	RM CRP	USED DAYS	SEQU 10A	SERV EVA	EXPT OPS	SERV FREQ	LENGTH REAR CAP	NO. OF APP	NO. OF MODULES
1	S001	EARTH OBSERV PALLET	400.	98.0	0.	0.	0.	3.50	2.00	3.50	7.00	2.00	4.00	3.50	2.50	0	SPCL	EARTH	2.0	0.0	300.0	16.0	16.0	150.0	1.0	0.0	5	1
2	S002	SYNTH APERTURE RADAR	400.	98.0	0.	0.	0.	2.50	1.00	2.50	6.00	2.00	4.00	10.00	1.00	0	SPCL	EARTH	2.0	0.0	10.0	2.0	2.0	5.0	1.0	0.0	2	1
3	S003	HETERODYNING CO2 LIDAR	400.	98.0	0.	0.	0.	1.20	1.00	2.50	4.00	1.00	4.00	1.00	1.00	0	SPKH	EARTH	2.0	0.0	50.0	2.0	5.0	5.0	3.0	0.0	0	0
4	S004	UPPER ATMOS RES PKG	400.	98.0	0.	0.	0.	4.00	2.00	4.00	7.00	2.00	0.00	2.15	0.90	0	SPCL	EARTH	2.0	0.0	200.0	35.0	19.0	145.0	2.0	0.0	1	0
5	GT01	SPACE STATION MODULES	400.	98.0	0.	0.	0.	11.00	0.00	11.00	7.00	0.00	4.00	15.00	0.00	0	SSSS	NONE	2.0	0.0	0.0	150.0	10.0	0.0	0.0	0.0	0	0
6	GT04	HI-INCL STATION RESUPPLY	400.	59.0	0.	0.	0.	8.00	0.00	0.00	6.00	0.00	4.40	1.00	0.00	0	SORS	NONE	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
7	SP01	SPACE SCIENCE SUBSATELLITE	400.	98.0	0.	0.	0.	2.40	1.00	2.40	4.00	1.00	4.00	0.00	0.00	0	FSXX	NONE	2.0	0.0	365.0	0.0	5.0	10.0	1.0	0.0	0	0
8	SP02	SPACE PHYSICS PALLET	400.	98.0	0.	0.	0.	10.00	4.00	10.00	5.00	2.00	4.00	0.40	2.00	0	SPCN	EARTH	2.0	0.0	36.0	17.0	14.0	54.0	2.0	0.0	28	3
9	SA01	VLBI/COSMIC RAY PKG	400.	99.0	0.	0.	0.	10.00	2.00	10.00	9.00	3.00	4.00	2.00	1.00	0	SPCL	INERT	2.0	0.0	365.0	0.0	9.0	67.0	2.0	0.0	2	0
10	SL08	RAD BIOLOGY IN SM MAMMALS	400.	98.0	0.	0.	0.	0.30	0.00	0.00	0.00	0.00	0.00	0.60	0.40	0	SSSA	NONE	2.0	0.0	365.0	16.0	0.0	30.0	4.0	0.0	0	0

Figure 2.1-4 Payload Description Data (Sample)

Table 2.1-1

Explanation of Terminology Used On Payload Description Data Input

(NOTE - SEE APPENDIX FOR MORE DETAILED EXPLANATION OF THESE PAYLOAD DESCRIPTIVE DATA ITEMS)

NO.	Simple payload identifies number.
CODE	This code number has a 2 letter prefix which identifies mission type (i.e., science and applications, commercial, technology demonstration, on operations) Commercial-Communications, etc.). The last 2 characters are sequence numbers. (Refer to Table for back to original source data).
NAME	Payload name
ORBIT-ALT	Orbit inclination, degrees
ORBIT-INCL	Orbit inclination, degrees
DELTA V'S	Delta velocity required to move payload from space station to its final orbit (UP), return payload from its orbit to the space station (DOWN), and whether are not the OTV is aerobraked (A/B).
MASSES	
PAYLD	Payload mass, in T
SUPT	Payload airborn support equipment, MT
RET	Payload mass when returned to Earth, MT
LENGTHS	
PAYLOAD	Payload stowed length, meters
SUPT	Payload ASE length, meters
PAYLD DIA	Payload stowed diameter, meters
POWER KW	Payload average power, kw
INTER VOLUME	Payload volume when installed within a space station module, M^3
MANIF RESTR	Manifesting restrictions

Table 2.1-1 (Cont'd)

Explanation of Terminology
Used On Payload Description Data
Input

OPS CODE	Mission operations code. First character-denotes free-flier (F), platform based (P), Space Station based (S), or sortie (SOR). Second character denotes not serviced (X), remotely serviced via unmanned TMS (T), recently serviced via manned TMS (M), serviced at the station after TMS returned (L), or serviced at the station after self-propelled retrieval (S), uses a berthing port (P) or no berthing port (S). The third character applied to payloads that require construction or servicing operations (C). The fourth character denotes low (L), medium (M), or high (H) complexity operations.
POINT'G DIR	Pointing direction
TIMES	
UP/DN	Time, in days, required to deliver payload to its orbit from/to space station.
ON ORB	Time, in days, required to activate or service payload after reaching its orbital location.
USED DAYS	Number of days per year payload is active.
SERV IVA	Number of man-days per year that are used to service the payload IVA.
SERV EVA	Number of man-days per year that are required to operate the experiment/payload.
SERV FREQ	Number of times per year the servicing operations are required.
LENGTH BEAM FAB	If a payload requires beam fabrication, how many meters of beam are required
NO. OF APP	Number of appendages to be deployed.
NO. OF MOD	Number of modules to be assembled to put the payload together.

SCIENCE AND APPLICATIONS MISSIONS AND INSTRUMENTS	MANIFEST NO.																		
	SA01	SA02	SA03	SA04	SA05	SL01	SL02	SL03	SL04	SL05	SL06	SL08	S001	S002	S003	S004	SP01	SP02	OTHER *
BACX0000 PARTICLE BEAM GENERATOR																		X	
BACX0001 EARTH OBSERVATION SENSOR DEF																			1
BACX0002 ORBITAL RADIO TELESCOPE					X														
BACX0003 SPACE PLASMA PHYSICS																		X	
BACX0004 ATMOSPHERIC SAMPLER																		X	
BACX0005 SOLAR MONITOR		X																	
BACX0006 MARGINAL ICE ZONE OBSERVATIONS													X						
BACX0007 LIDAR-CIDS													X						
BACX0008 HEAVY ION DETECTOR																		X	
BACX0009 ASTROMETRIC OPTICAL TELESCOPE			X																
BACX0010 ATMOSPHERIC GEN CIRC EXP (AGCE)																X			
BACX0011 SPACE ENVIRONMENT MONITORING																		X	
BACX0012 GEOPHYSICAL FLUID FLOW CELL EXPT																			2
BACX0013 MUSCLE METABOLISM (NMR)																			5
BACX0014 HIGH RESOLUTION DOPPLER IMAGER																X			
BACX0015 LARGE ARRAY DOPPLER IMAGER																			3
BACX0016 GRAVITY WAVES EXPT																			2
BACX0017 S.S. GAMMA RAY TELESCOPE			X																
BACX0018 COSMIC RAY PHYSICS																		X	
BACX0019 OCEAN RESEARCH/REMOTE SENSING OF													X						
BACX0020 BURN HEALING STUDY																			2
BACX0021 MULTISPECTRAL SENSOR													X						
BACX0022 OCEAN REMOTE SENSING													X						
BACX0023 OCEAN RESEARCH INSTRUMENTATION													X						
BACX0025 SPACE PLASMA PHYSICS (SPACELAB 6)																			1
BACX0026 PLASMA PHYSICS SPACE																	X		
BACX0027 SPLIT LANGMUIR PROBE (SLUPP)																	X		
BACX0028 IONOSPHERE/ATMOSPHERE MONITOR																X			
BACX0030 ACTIVE CAVITY RADION SOLAR IRRAD																			
BACX0031 PARTICLE ENERGY MONITOR																	X		
BACX0032 IMAGING GAMMA-RAY TELESCOPE FACI				X															
BACX0034 PULMONARY FUNC IN WEIGHTLESSNESS																			5
BACX0035 PRIMATE FACILITY																			5
BACX0036 SPACELAB 1 GERMAN D-1 MISSION																			4
BACX0037 MAMMALIAN GRAVITY RECEPTOR																			5
BACX0039 FIELD LINE MAPPING																		X	
BACX0040 GENERIC ENG/VEGETATION SPECIES I								X											
BACX0042 EARTH OBSERVATION FACILITY													X						
BACX0043 EARTH OBSERVATION FACILITY													X						
BACX0044 EARTH OBSERVATION FACILITY													X						
BACX0045 EARTH OBSERVATION FACILITY													X						
BACX0046 EARTH OBSERVATION FACILITY													X						
BACX0048 EARTH OBSERVATION FACILITY													X						
BACX0049 EARTH OBSERVATION FACILITY													X						
BACX0051 EARTH OBSERVATION FACILITY													X						
BACX0052 EARTH RESOURCES FACILITY													X						
BACX0053 EARTH OBSERVATION FACILITY													X						
BACX0054 S.S. INCOHERENT SCATTER RADAR													X						
BACX0055 S.S. DIGITAL HF RADAR																			3
BACX0056 SPACELAB-2																			4
BACX0057 ENAIP													X						
BACX0058 SHORT LIVED PHENOMENA													X						
BACX0059 EARTH VIEWING PARAMETER ANALYSIS													X						
BACX0060 LARGE ANTENNA SYSTEMS																			14
BACX0061 WAVE MONITORING													X						
BACX0062 OCEAN SURFACE CURRENTS													X						

* 1 COMBINED WITH OTHER MISSION(S)
2 INSUFFICIENT DATA AVAILABLE
3 OVERLAPPED OTHER MISSION
4 NOT APPLICABLE
5 WILL BE ACCOMPLISHED IN LIFE SCIENCE RESEARCH FACILITY
6 NICE TO HAVE, BUT NOT A REQMT
7 DELETED
8 ACCOMPLISHED IN SCI & APP MISSIONS
9 ACCOMPLISHED ON SHUTTLE
10 ACCOMPLISHED IN COMMERCIAL MISSIONS
11 NOT VIABLE AT THIS TIME
12 NOT MANIFESTED
13 CARRY-ON EXPERIMENT
14 ACCOMPLISHED IN TECH DEV MISSIONS

Table 2.1-2. Traceability Matrix

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SCIENCE AND APPLICATIONS MISSIONS AND INSTRUMENTS	MANIFEST NO.																		
	SA01	SA02	SA03	SA04	SA05	SL01	SL02	SL03	SL04	SL05	SL06	SL08	S001	S002	S003	S004	SP01	SP02	OTHER *
BACX0063 MINERAL EXPLORATION													X						
BACX0064 AGRICULTURAL CROP MONITORING													X						
BACX0065 AGRICULTURAL CROP MONITORING													X						
BACX0066 FOREST MONITORING													X						
BACX0067 SHADOW AIDED TARGET DISCRIMINATION													X						
BACX0201 PART ACCEL																		X	
BACX0202 WAVE INJECT																	X		
BACX0203 PLASMA E SPECT																	X		
BACX0204 PLASMA DIAG																	X		
BACX0205 UHF/VLF REC																	X		
BACX0206 CHEM REL CANS																	X		
BACX0207 VIDEO CAMERAS																	X		
BACX0208 ION MASS SPEC																	X		
BACX0209 IR LIDAR (WIND)																	X		
BACX0210 VIS LIDAR (TEMP)																	X		
BACX0211 IMAG UV-IR SPECT																		X	
BACX0212 UV-IR TELESCOPE																		X	
BACX0213 XRAY TEL (ATMOS)																		X	
BACX0214 MAG CONFINE LAB																		X	
BACX0215 RETRO REFL TRAKR																		X	
BACX0216 BACKSCAT RADAR																X			
BACX0301 IRTEL (SIRTF)		X																	
BACX0302 VLBI	X																		
BACX0303 XTEL		X																	
BACX0304 XTEL		X																	
BACX0305 OPTEL			X																
BACX0306 UVTEL (STARLAB)			X																
BACX0307 HRXS		X																	
BACX0308 LAMAR																			11
BACX0310 SUPERMAG	X																		
BACX0311 HNE	X																		
BACX0312 LACRD	X																		
BACX0314 RADTEL			X																
BACX0315 MRSA			X																
BACX0316 IMAGSPECT			X																
BACX0317 GFRAVWAVE																			2
BACX0318 GFFC																			13
BACX0319 SCRN	X																		
BACX0320 SOT																			13
BACX0401 IMAGING SPECTROMETER													X						
BACX0402 LASER RANGER													X						
BACX0403 MULTISPECTRAL SCANNER													X						
BACX0404 SAR														X					
BACX0405 OPTICAL LIDAR															X				
BACX0406 CAMERA HI-RES													X						
BACX0407 SCATTEROMETER													X						
BACX0408 INTERFEROMETER																			13
BACX0409 VIDEO CAMERA																			13
BACX0410 OPTICAL TELESCOPE																			13
BACX0411 RADAR SOUNDER ALTIMETER													X						
BACX0412 MICROWAVE RADIOMETER													X						
BACX0414 MICROWAVE ALTIMETER																			13
BACX0415 MICROWAVE SPECTROMETER																			13
BACX0416 DATA COLL PKG													X						
BACX0501 HUMAN CARDIO PULMONARY SYSTEM						X													
BACX0502 BODY FLUIDS							X												

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14 ACCOMPLISHED IN TECH DEV MISSIONS

Table 2.1-2. Traceability Matrix (Continued)

ORIGINAL PAGE IS
OF POOR QUALITY

SCIENCE AND APPLICATIONS MISSIONS AND INSTRUMENTS	MANIFEST NO.																		
	SA01	SA02	SA03	SA04	SA05	SL01	SL02	SL03	SL04	SL05	SL06	SL08	S001	S002	S003	S004	SP01	SP02	OTHER *
BACX0503 HUMAN SENSORY SYSTEMS						X													
BACX0504 MUSCULOSKELETAL (HUMAN)						X													
BACX0505 BONE LOSS							X												
BACX0506 MUSCLE LOSS							X												
BACX0507 FLUID AND ELECTROLYTE							X												
BACX0508 NON-HUMAN CARDIOVASCULAR							X												
BACX0509 NON-HUMAN MAMMALIAN METABOLISM							X												
BACX0510 VESTIBULAR PHYSIO IN SM MAMMALS							X												
BACX0511 VESTIBULAR FUNCTION IN SM MAMMAL									X										
BACX0512 RADIATION BIOLOGY IN SM MAMMALS												X							
BACX0513 ANIMAL DEVELOPMENT										X									
BACX0514 ANIMAL REPROD IN SM MAMMALS									X										
BACX0515 PLANT PHYSIOLOGY								X											
BACX0516 PLANT DEVELOPMENT								X											
BACX0517 CLOSED ENVIRON LIFE SUPP SYS											X								
BACX0601 AIR PART SAMP																			5
BACX0602 PART ANAL												X							
BACX0603 ARTER PRESS REC						X													
BACX0604 AUDIOMETER						X													
BACX0605 AUTORADIOGRAPH												X							
BACX0606 BEHAV EVAL KIT						X													
BACX0607 BLOOD CHEM ANAL						X													
BACX0608 BLOOD GAS ANALY						X													
BACX0609 LABWARE						X													
BACX0610 STILL CAMERA						X													
BACX0611 CARDIOGRAPH						X													
BACX0612 H/S CENTRIFUGE						X													
BACX0613 MICRO CENTRIFUGE						X													
BACX0614 1g CENTRIFUGE																			5
BACX0615 CHEM ANAL SET						X													
BACX0616 CRYOGENIC SYS						X													
BACX0617 DATA MANAGEMENT UNIT						X													
BACX0618 DECOMPRESSION CHAMBER																			6
BACX0619 DEHYDRATED MEDIA						X													
BACX0620 DENTAL INSTRUMENTS						X													
BACX0621 DESSICATOR (VAC)							X												
BACX0622 DIAGNOSTIC IMAGE SYS						X													
BACX0623 X-RAY							X												
BACX0624 DISSECTION KIT							X												
BACX0625 DOPPLER FLOWMETER							X												
BACX0626 DOSIMETER												X							
BACX0627 DYANOMOMETER						X													
BACX0628 ECG/EVG						X													
BACX0629 EEG						X													
BACX0631 EMG						X													
BACX0633 EOG						X													
BACX0634 GAS CHROMATGRAPH						X													
BACX0635 HISTOLOGY KIT						X													
BACX0636 HOLDING FACILITY						X													
BACX0637 INCUBATOR						X													
BACX0638 INJECTION EQUIPMENT							X												
BACX0639 IV FLUID SYSTEM						X													
BACX0640 LAMINAR WORK TABLE						X													
BACX0641 LIM PLETHYSMOGRAPH						X													
BACX0642 LWR BODY NEG PRES. UNIT						X													
BACX0643 LYOPHILIZE							X												

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Table 2.1-2. Traceability Matrix (Continued)

SCIENCE AND APPLICATIONS MISSIONS AND INSTRUMENTS	MANIFEST NO.																		OTHER *
	SA01	SA02	SA03	SA04	SA05	SL01	SL02	SL03	SL04	SL05	SL06	SL08	S001	S002	S003	S004	SP01	SP02	
BACX0644 MACROMASS MEASURE						X													
BACX0645 MICROMASS MEASURE																			
BACX0646 METABOLIC ANAL.																			
BACX0647 MICROBIOLOGY KIT																			
BACX0648 MICROTOME						X													
BACX0649 MICRO MANIPULATOR							X												
BACX0650 MICROSCOPE STEREO						X													
BACX0651 UV/LIGHT/IR						X													
BACX0652 ELECTRON							X												
BACX0653 OHMMETER																			5
BACX0654 OSCILLOSCOPE						X													
BACX0655 OVEN							X												
BACX0656 PH METER						X													
BACX0657 PHYSIOLOGIC GAS ANAL						X													
BACX0658 PLANT TOOLS								X											
BACX0659 PLATE SCAN CTR						X													
BACX0660 POLARGRAPHIC O_2/CO_2								X											
BACX0661 PRESERVATION MATERIAL						X													
BACX0662 PULMONARY FUNCTION MEASURE KIT						X													
BACX0663 PSYCHOMETRICS UNIT						X													
BACX0664 RADIOBIOLOGY UNIT												X							
BACX0665 REFRIGERATOR						X													
BACX0666 ROTATING LITTER CHAIR																			5
BACX0669 STAIN KITS						X													
BACX0670 STERILIZERS						X													
BACX0671 SIGNAL GENERATOR						X													
BACX0672 SURGICAL INSTRUMENT KIT						X													
BACX0673 TEMPERATURE BLOCK						X													
BACX0674 CLOCK/TIMER						X													
BACX0675 TISSUE CULTURE CHAMBER						X													
BACX0676 TRACE GAS MONITOR							X												
BACX0677 TV/VIDEO CINEMA						X													
BACX0678 URINE ANALYZER						X													
BACX0679 VET MED KIT							X												
BACX0680 VOLTMETER							X												
BACX0681 WASHER, CAGE							X												
BACX0682 WASHER, TOOLS,							X												

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14 ACCOMPLISHED IN TECH DEV MISSIONS

Table 2.1-2. Traceability Matrix (Continued)

COMMERCIAL MISSION	MANIFEST NO.										
	CC04	CC05	CM01	CM02	CM03	CM04	CM05	CM06	CM07	CM08	OTHER
BACX1000 MULTIBEAM COMM SATELLITE	X										
BACX1001 RECONFIGURATION COMM SATELLITE		X									
BACX1002 FLOAT ZONE CRYSTAL PROCESSING			X								
BACX1003 VAPOR EPITAXIAL CRYSTAL GROWTH			X								
BACX1004 ELECTROEPITAXIAL CRYSTAL GROWTH											1
BACX1005 CONTINUOUS FLOW ELECTROPHORESIS											1
BACX1006 COLLAGEN PROCESSING											7
BACX1007 INFRARED DETECTOR PRODUCTION			X								
BACX1008 ELECTROEPITAXIAL CRYSTAL GROWTH				X							
BACX1009 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1010 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1011 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1012 ELECTROEPITAXIAL CRYSTAL GROWTH				X							
BACX1013 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1014 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1015 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1016 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1017 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1018 ELECTROEPITAXIAL CRYSTAL GROWTH					X						
BACX1019 ELECTROEPITAXIAL CRYSTAL GROWTH				X							
BACX1020 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1021 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1022 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1023 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1024 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1025 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1026 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1027 ELECTROEPITAXIAL CRYSTAL GROWTH				X							
BACX1028 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1029 ELECTROEPITAXIAL CRYSTAL GROWTH						X					
BACX1030 CONTINUOUS FLOW ELECTROPHORESIS							X				
BACX1031 CONTINUOUS FLOW ELECTROPHORESIS								X			
BACX1032 CONTINUOUS FLOW ELECTROPHORESIS								X			
BACX1033 CONTINUOUS FLOW ELECTROPHORESIS								X			
BACX1034 CONTINUOUS FLOW ELECTROPHORESIS								X			
BACX1035 CONTINUOUS FLOW ELECTROPHORESIS							X				
BACX1036 CONTINUOUS FLOW ELECTROPHORESIS								X			
BACX1037 CONTINUOUS FLOW ELECTROPHORESIS								X			
BACX1038 CONTINUOUS FLOW ELECTROPHORESIS								X			
BACX1039 CONTINUOUS FLOW ELECTROPHORESIS								X			
BACX1040 GLASS PROCESSING FOR OPTICAL FIBERS										X	

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14 ACCOMPLISHED IN TECH DEV MISSIONS

Table 2.1-2. Traceability Matrix (Continued)

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TECHNOLOGY DEVELOPMENT MISSION	MANIFEST NO.									OTHER
	TC01	TE01	TE02	TM01	TM02	TM03	TP01	TP02	TS01	
BACX2000 EARTH OBSERVATION INST DEV MAPS										8
BACX2001 PASSIVE MW RADIOM (LSS-3)						X				
BACX2002 EARTH OBSERVATION INSTR DEVELOP										8
BACX2003 SATELLITE DOPPLER METEOR RADAR										8
BACX2004 MICROWAVE REMOTE SENS TECH										8
BACX2005 EARTH FEATURE IDENTIFICATION										8
BACX2006 ZERO-G BROMINE PHASE SEPARATION									X	
BACX2007 EARTH BOUND ORIENTED INST DEV										8
BACX2008 LARGE SOLAR COLL (LSS-6)										1
BACX2009 SPACE COMPONENT LIFETIME TECH									X	
BACX2010 MATERIALS & COATING TECHNOLOGY										1
BACX2011 LIQUID DROPLET RADIATOR			X							
BACX2012 ION THRUSTER EFFECT ON LEO POWER									X	
BACX2013 CREW SYSTEMS EMESIS STATION									X	
BACX2014 DISHWASHER/CLOTHES WASHER									X	
BACX2015 CRYOGENIC FLUID STORAGE TECHNOLOGY										1
BACX2016 CRYOGENIC LIFETIME TECHNOLOGY										1
BACX2017 FLUID MANAGEMENT TECHNOLOGY										9
BACX2018 FIRE SAFETY TECHNOLOGY									X	
BACX2019 TETHER DYNAMICS TECHNOLOGY									X	
BACX2020 LARGE SPACE POWER SYSTEM TECH		X								
BACX2021 TEST SOLAR-PUMPED LASERS										1
BACX2022 LASER-TO-ELECTRIC ENERGY CONVERS										1
BACX2023 SOLAR-SUSTAINED PLASMAS										7
BACX2024 LOW COST MODULAR SOLAR PANEL TECH		X								
BACX2025 LASER COMM TRACKING DEVELOP										1
BACX2026 MULTI-FREQ HIGH GAIN ANTENNA										4
BACX2027 SINGLE CRYSTAL RHODIUM WAFERS									X	
BACX2028 LASER PROPULSION TEST										1
BACX2029 HABITABILITY CRITERIA VALIDATION									X	
BACX2030 MANIPULATOR CONTROLS TECHNOLOGY										1
BACX2031 SATELLITE SERVICING TECHNOLOGY										1
BACX2032 OTV SERVICING TECHNOLOGY										1
BACX2033 SPACECRAFT STRAIN & ACOUSTIC EMI										1
BACX2034 SPACECRAFT HANGAR (LSS-2)				X						
BACX2035 MATERIALS EXPOSURE LAB									X	
BACX2036 PRECISION OPTICAL SYSTEM (LSS-4)					X					
BACX2037 CONST & STORAGE FAC (LSS-1)				X						
BACX2038 LARGE STRUCTURES TECH EXPERIMENT										1
BACX2039 ATTITUDE CONTROL-SYSTEM IDENT										1
BACX2040 ATTITUDE CONTROL-ADAPTIVE CONTROL										1
BACX2041 ATTITUDE CONTROL DIST CONTROL										1
BACX2042 ZERO-G ANTENNA RANGE COMM EXP										1
BACX2043 DYNAMICS OF LIGHTLY LOADING STRUCT										1
BACX2044 SPACECRAFT MATERIALS TECHNOLOGY										1
BACX2045 SPACECRAFT CONTROL TECH DEV										1
BACX2046 ADVANCED CONTROL DEVICE TECH DEMO										1
BACX2047 THERMAL SHAPE CONTROL TECHNOLOGY										1
BACX2048 ACTIVE OPTICS TECHNOLOGY										1
BACX2049 GEODESIC SPHERICAL STRUCTURES										7
BACX2050 LARGE SPACE STRUCTURE TECHNOLOGY										1
BACX2051 CONTROLLED ACCELERATION PROPULSION										7
BACX2052 TELEOPERATOR REAL TIME COMM										7
BACX2053 LARGE ANTENNA DEVELOPMENT										7
BACX2054 FAB OF LIGHTWEIGHT CRYO HEAT PIPE										7
BACX2055 ADV ADAPTIVE CONTROL TECH DEMO										7

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Table 2.1-2. Traceability Matrix (Continued)

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TECHNOLOGY DEVELOPMENT MISSION

	MANIFEST NO.									
	TC01	TE01	TE02	TM01	TM02	TM03	TP01	TP02	TS01	OTHER
BACX2056 SOLAR PUMPED LASERS										7
BACX2057 MATERIALS PROC TECH-PROC & TECH										10
BACX2058 ELECTROPHORESIS SEPARATION										10
BACX2059 MANIPULATOR DEVELOP & TEST FACILITY									X	
BACX2060 SHOWER STATION									X	
BACX2061 TRASH MANAGEMENT									X	
BACX2062 CRYOGENIC FLUID STORAGE TECH										1
BACX2063 PROP TRANSFER TECH DEMO (OTV-1)							X			
BACX2064 PROP STORAGE TECH DEMO (OTV-2)							X			
BACX2065 RNDZVX, DCKG, BERTH TECH DEMO (OTV)								X		
BACX2066 OTV MAINT TECH DEMO (OTV-4)								X		
BACX2067 PAYLOAD/OTV INTEG TECH DEMO (OTV)								X		
BACX2068 CLOSED ECLS FOR SPACE STATION									X	
BACX2069 SOLAR ARRAY ADDITION TECH DEMO									X	
BACX2070 FORMATION FLYING TECH DEMO (SS-2)									X	
BACX2071 SATELLITE ASSY TECH DEMO (SS-3)									X	
BACX2072 ON-BOARD SAT SERV TECH DEMO									X	
BACX2073 INSITU SAT UNMANNED SERV TECH DEMO	X									
BACX2074 SURFACE INTERACTION W/RCS PLUME									X	
BACX2075 ROBOTICS	X									
BACX2076 COMPOUND SEMICONDUCTOR CRYSTALS										10

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14 ACCOMPLISHED IN TECH DEV MISSIONS

Table 2.1-2. Traceability Matrix (Continued)

FLIGHT SUPPORT TRAFFIC MODEL

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
			TRAFFIC MODEL YEAR															
1	SO01	EARTH OBSERV PALLET	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	SO02	SYNTH APERTURE RADAR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3	SO03	HETERODYNING CO2 LIDAR	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
4	SO04	UPPER ATMOS RES PKG	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
5	OT03	SPACE STATION MODULES	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0
6	OT04	HI-INCL STATION RESUPPLY	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2
7	SP01	SPACE SCIENCE SUBSATELLITE	0	0	1	0	-1	0	1	0	0	-1	0	0	0	0	0	0
8	SP02	SPACE PHYSICS PALLET	0	0	0	1	0	0	0	-1	0	0	1	0	0	0	0	0
9	SA01	VLBI/COSMIC RAY PKG	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
10	SL08	RAD BIOLOGY IN SM MAMMALS	0	0	0	0	0	0	0	1	0	0	-1	0	0	1	0	0

NOTE: "– 1" INDICATES A RETURN-TO-EARTH PAYLOAD

Figure 2.1-5. Sample Payload Manifest Schedule

2.2.2.1 Manifesting Parameters

These parameters include such things as shuttle orbiter cargo bay dimensions, maximum payload mass, center-of-gravity constraints, STS turnaround times, ITV payload mass and size constraints, TMS payload mass constraints, docking tunnel parameters, mini-tanker parameters, etc.

2.2.2.2 Manifesting Rules

These rules include priorities for pairing of payloads with each other and/or mini-tanker manifest restrictions, space-based or ground-based OTV options, space stations or no-space station options mini-tanker or no-mini tanker etc.

The manifesting analysis output data (a sample is shown in Figure 2.1-6) includes the following data on a year-by-year basis:

- o Flight-by-flight Payload Manifest
- o No. of shuttle flights

- No. of TMS flight operations
- No. of manned TMS flights
- No. of self-propelled satellite servicing operations
- Quantity of TMS and satellite propellant used
- No. of OTV's reused
- No. of OTV's expended
- No. of Space Station flight servicing operations
- No. of Space Station construction operations
- No. of HLLV flights
- Total orbiter fleet time
- Ideal minimum orbiter fleet size
- OTV propellant required
- OTV propellant left over from previous year
- Propellant delivered by mini-tanker
- Propellant delivered by ET scavaging

YEAR 1996

MANI- FEST #	KEY REF	DESCRIPTION	MATCHED WITH	NO. FLTS	OTV USED	OTV EXP	P/L BAY LENGTH	LAUNCH MASS	TIME ON ORBIT	SP STA OPERATION
1	OTO4	HI-INCL STATION RESUPPLY	SPACE SCIENCE SUBSATELLITE	1	C	C	10.0	1C.4	4.0	FS
2	OTO4	HI-INCL STATION RESUPPLY		1	0	C	6.0	E.C	2.0	

** - MANIFESTED WITH MINITANKER

```
NO. OF SHUTTLE FLIGHTS      2
 NO. OF TMS OPS           0
 NO. OF MANNED TMS OPS          C
 NO. OF SELF:PROP SAT SERV OPS        1
 TMS & SATELLITE PROPELLANT USED           C.05
NO. OF OTV REUSE FLIGHTS      0
NO. OF OTVS EXPENDED       0
SPACE STATION FLT SERVICE OPS      1
SPACE STATION CONSTR OPS      0
SPACE STATION PROP XFER OPS      C
HLLV FLIGHTS      C
 FLEET TIME ON ORBIT =      6.0 DAYS
 TOTAL FLEET TIME =     76.0 DAYS
 IDEAL MIN FLEET SIZE =      0.24 VEHICLES
```

Figure 2.1-6 Sample Manifesting Analysis Output

2.2.3 Operations Analysis

The manifesting analysis output was coupled to our operations analysis software module. This module was used to derive statistics on space station crew utilization and accommodations requirements.

2.2.3.1 Crew Utilization Analysis

We employed a means of deriving the total time a payload is on-board the space station, crew skills utilization statistics and total crew size. These statistics can be printed out in a flight-by-flight on a yearly summary basis.

Payload Time Onboard Space Station

From our space station data base, we have assembled a large body of timeline analyses of the various operations conducted at a space station. We have used this data to create algorithms that compute the duration that a payload is at the space station. The duration time computation also utilized the operations times specified for each payload (see Figure 2.1-4 and Table 2.1-1).

Crew Skills Utilization—Table 2.1-3 defines the 16 crew skills we have used in our analysis. We have created matrices that allocate these skills to the various steps in the operations required to process the various types of payloads. These skill utilizations are matched with the computed duration times of the various activities. The program keeps the books on the total demand on each skill as each year's payload manifest is processed. Figure 2.1-7 shows the crew utilization statistics that are summarized on a year-to-year basis.

2.2.3.2 Space Station Accommodations Analysis

Our operations analysis software module also keeps statistics on payload demands for berthing ports, electrical power, internal volume, and pointing requirements.

Berthing Ports—One of the characters in the OPS CODE (see Table 2.1-1) specified which payloads require a berthing port. These were used only for the pressurized mission modules (e.g., life sciences research module). The software keeps a record of these demands until the traffic model shows the module being returned to Earth.

Electrical Power—The software keeps statistics on the payload demands for space station electrical power based on the POWER defined on the payload descripton input (see Figure 2.1-4). This power was the analyst's estimate of the average power demand (not necessarily the peak power demand). The power results that are printed out on a year-by-year basis is the time-averaged power demand for the payloads attached to the space station power statistics for platform mounted or free flyer payloads were not included.

Table 2.1-3 CREW SKILLS DESCRIPTION

Crew Type	Skill Requirements
Medical/Biological Researcher	o Intermediate training in medicine and medical science o Basic training in Zoology and Botany o Basic skills in mechanical electrical and electronic diagnostics, troubleshooting and repair o EVA qualified
Physical Science Researcher	o Basic to advanced training in Space Physics, depending on mission o Intermediate skills in mechanical, electrical and electronic diagnostics, troubleshooting and repair o EVA qualified
Earth And Ocean Observations	o Superior visual detection and recognition skills o Intermediate to advanced geology and geography training, depending on mission. o Basic skills in mechanical, electrical and electronic diagnostics, troubleshooting and repair o EVA qualified
Engineering	o Advanced skills in mechanical, hydrolic, pneumatic, electrical avionics and electronic diagnostics, troubleshooting and repair o Training in computer hardware and software o EVA proficient
Astrophysics	o Basic to advanced training in astrophysics, depending on mission o Intermediate skills in mechanical, electrical and electronic diagnositcs, troubleshooting and repair o EVA qualified
Space Craft Systems-Data	o Advanced training in computer hardware including peripherals o Advanced training in communications systems o Advanced skills in electrical and electronic diagnostics, troubleshooting and repair o EVA proficient
Space Craft Systems-Electrical	o Intermediate training in electrical power systems. o Advanced skills in electrical diagnostics, troubleshooting and repair o EVA proficient
Space Craft Systems-Mechanical	o Intermediate training in properties of metals and composites used in spacecraft structures and equipments o Advanced skills in mechanical diagnostics, troubleshooting and repair o EVA proficient

Table 2.1-3 CREW SKILLS DESCRIPTION (Cont'd)

Crew Type	Skill Requirements
Space Craft Systems-Fluids	o Advanced training in hydraulics, and hydraulic systems o Advanced skills in hydraulic diagnostics, troubleshooting and repair o EVA proficient
Space Craft Systems Operations	o Advanced training in computer hardware, communications systems, electrical systems, mechanics, and hydraulics o Advanced skills in diagnostics, troubleshooting and repair o EVA qualified
EVA Crane Operations	o Proficient at remote control o Proficient at transporting and positioning masses with manipulators o Intermediate training in space station flight dynamics o EVA proficient
EVA Service Technicians	o Advanced training in diagnostics, troubleshooting and repair of electrical, electronic, mechanical and hydraulic systems o EVA proficient
Manned OTV Pilot	o Pilot astronauts training and experience with aircraft of a wide range of performance characteristics o Proficient at checking with and maneuvering payloads o Training in vulnerable aspects of satellites o Proficient at EVA
TMS Pilot	o Advanced skills at remote operations o Pilot astronaut training o EVA qualified
Materials Science	o Basic training in mechanical engineering o Advanced training in relevant materials science processes (only required during development stages) o Intermediate training in diagnostics, troubleshooting, and repair of electrical, electronic and mechanical systems

ORIGINAL PAGE IS
OF POOR QUALITY

UPDATED L DURATION AT SP STA 65.0 WORK DAYS
RESEARCH MISSION RESULTS

CREW SKILL	MANDAYS
NO SPECIAL SKILL	6.500
ASTROPHSICS	65.000
S/C SYS - ELEC	3.250
S/C SYS - FLUIDS	3.250
SP STA SYS OPS	3.250

DURATION SUMMARY FOR PAYLOAD NO. 21 SA02 IN MANDAYS/YR

SERVICING OPERATIONS 0.0
SCIENCE & TECH DEMO 65.0

PAYLOAD WITH KEY SA04 ASTROPHYSICS OBSERVATORIES

SATELLITE SERVICING OPERATIONS

UNADJUSTED DURATIONS
REMOTE SERVICE = 6.000
TEST & C/O = 3.400
TMS LAUNCH = 0.082
TMS OPS = 3.000
TMS CREW OPS = 3.000
TMS CAPTURE/BRTH = 0.042
TMS MAINT/REFUEL = 1.100
CREW MOD MAINT = 1.710

ADJUSTED SERVICING TIME FOR 23 SA04 38.5 DAYS
SATELLITE SERVICING MISSION RESULTS

CREW SKILL	MANDAYS
NO SPECIAL SKILL	15.278
S/C SYS - DATA	40.774
S/C SYS - ELEC	10.555
S/C SYS - MECH	29.524
S/C SYS - FLUIDS	8.513
SP STA SYS OPS	41.723
EVA SERVICE TECH	14.238
TMS PILOT	50.921

SCIENCE & APPLICATIONS ONBOARD MISSIONS

SCIENCE & APPLICATIONS ONBOARD MISSIONS

DURATION SUMMARY FOR PAYLOAD NO. 46 SA05 IN MANDAYS/YR

SERVICING OPERATIONS 61.0
SCIENCE & TECH DEMO 0.0

SKILL MIX SUMMARIES LOW INCLINATION

SKILL MIX DETAILS FOR ACCUMULATED MISS

CREW SKILL	***SCIENCE MISSIONS***				***COMMERC MISSIONS***				***TECH DEV MISSIONS**				****OPER SUPPORT*****			
	OPS	SERV	MSN OP	CONST	OPS	SERV	MSN OP	CONST	OPS	SERV	MSN OP	CONST	OPS	SERV	MSN OP	CONST
NO SPECIAL SKILL	0.0	52.9	83.0	0.0	0.0	206.4	0.0	0.0	0.0	0.0	4.0	0.0	0.0	67.2	0.0	0.0
MED/BIO RESEARCH	0.0	0.0	829.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PHYS SCI RESEARC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EARTH. OCEAN OBS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENGINEERING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0
ASTROPHSICS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S/C SYS - DATA	0.0	150.5	0.0	0.0	83.9	451.1	0.0	67.8	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
S/C SYS - ELEC	0.0	31.7	41.5	0.0	97.0	181.4	0.0	45.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
S/C SYS - .1ECH	0.0	91.4	0.0	0.0	86.8	447.6	0.0	45.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
S/C SYS - FLUIDS	0.0	26.9	41.5	0.0	79.3	141.6	0.0	41.3	0.0	0.0	4.0	J.0	23.2	0.0	0.0	0.0
SP STA SYS OPS	0.0	153.3	41.5	0.0	190.1	488.5	0.0	255.8	0.0	0.0	2.0	0.0	147.8	470.4	0.0	0.0
EVA CRANE OP	0.0	0.0	0.0	0.0	155.1	0.0	0.0	90.5	0.0	0.0	1.0	0.0	80.6	67.2	0.0	0.0
EVA SERVICE TECH	0.0	42.7	0.0	0.0	198.6	213.6	0.0	79.0	0.0	0.0	1.0	0.0	80.6	67.2	0.0	0.0
MANNED OTV PILOT	0.0	0.0	0.0	0.0	136.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
TMS PILOT	0.0	152.8	0.0	0.0	0.0	856.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MATLS SCIENCE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MANDAYS BY MISSION

SCIENCE & APP	COMMERCIAL	TECH DEV	OPS SUPPORT
1739.	4639.	40.	1004.

MANDAYS BY SKILL

SKILL	MANDAYS
NO SPECIAL SKILL	413.4
MED/BIO RESEARCH	829.5
PHYS SCI RESEARC	0.0
EARTH. OCEAN OBS	0.0
ENGINEERING	20.0
ASTROPHSICS	0.0
S/C SYS - DATA	756.3
S/C SYS - ELEC	398.1
S/C SYS - MECH	672.4
S/C SYS - FLUIDS	357.9
SP STA SYS OPS	1748.5
EVA CRANE OP	394.5
EVA SERVICE TECH	682.8
MANNED OTV PILOT	139.0
TMS PILOT	1009.0
MATLS SCIENCE	0.0

Figure 2.1-7. Sample—Crew Activities Summary for a Mission

Internal Volume—The payload input data denoted how much internal volume (if applicable) will be required to install the payload. This does not include the internal volume of pressurized laboratory modules. The software sums these demands on a yearly basis.

Pointing Requirements—The payload input data also denoted the pointing requirements. The software uses the computed time-onboard-space-station to create a timeline graphical output showing the pointing requirements of all payloads delivered each year, see Figure 2.1-8.

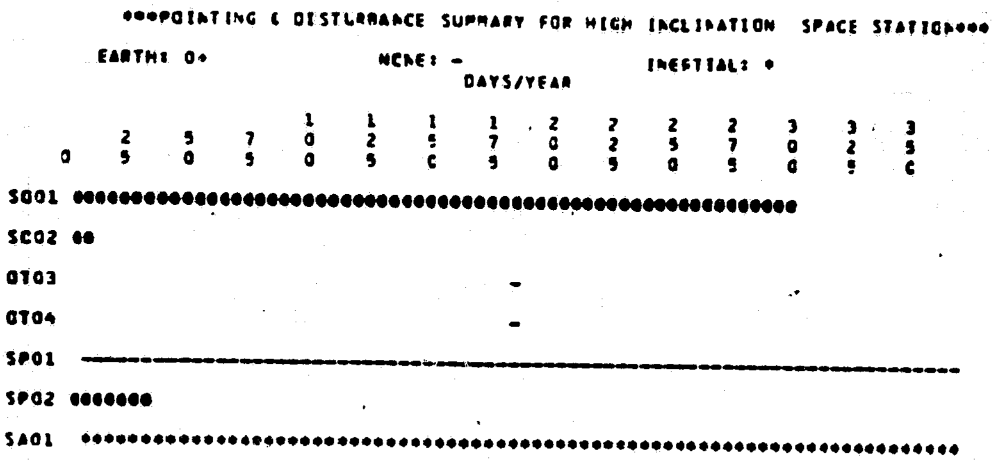

Figure 2.1-8. Sample Pointing and Disturbance Summary Output

2.3 SUMMARY RESULTS

We have summarized the mission analysis data based on three different scenarios of operational capability. In Section 4.0, these scenarios are fully described. Scenario A is a <u>"Mission constrainted"</u> scenario wherein the space station system buildup is paced by the mission demands. Scenario B is a <u>"station constrained"</u> scenario wherein the space station buildup sequence dictates the sequence of payload deliveries. The third scenario, Scenario C, is a <u>"no space station"</u> case used for comparison.

The final results of the mission analyses for these scenarios are found in Section 5.0. These results imposed mission accommodation requirements some of which were entered into the requirements document, Volume 3. These requirements were then utilized in defining the architectural optons described in Volume 4. Finally, the commercial missions were analyzed to define the economic benefits to be realized by utilizing the space station system. The results of this analysis are found in Section 6.0.

3.0 USER MISSION DESCRIPTIONS

This section contains the summary descriptions of the user missions analyses. The science and applications missions are discussed in Section 3.1. The commercial missions are discussed in Section 3.2. Technology development missions are described in Section 3.3. Space Operations missions are discussed in Section 3.4.

These sections contain descriptions of the approach used to define the potential missions the tasks required for the mission operations, the necessary crew skills, and the space station accommodation requirements. Each of these subsections is based on data bases too voluminous to include in this document. Within each write-up, the reader may be referred to a Volume 7 Data Book which will contain the detailed data.

3.1 SCIENCE AND APPLICATIONS MISSIONS

Our understanding of the natural world in which we live has grown dramatically as a consequence of science and applications research from space. Development of a Space Station will create the opportunity for long-term observations with more sophisticated instruments under astronaut supervision that should generate even greater advances.

The material covered in this section includes all space science research and those applications of a noncommercial nature that are performed on spacecraft. Space science has been categorized along major subject disciplines that are distinguished by similar instrumentation. The categories are: (1) space environment, (2) astrophysics, (3) earth environment, (4) life sciences, and (5) materials sciences. Applications are distributed among these major headings; in particular earth observations are included in category (3) and life support studies are in (4). Product development studies that have established procedures such as synthesis of purer medical and industrial materials are discussed in the Commercial Section (3.2). Research on Space Station functional systems is discussed in the Technology Development Section (3.3).

Space Science and Applications research from the Space Station will use a diverse collection of instruments. Selection of instrument payloads will depend on many factors such as relative technical importance, appropriateness for Space Station, benefit to mankind, cost, launch weight, power requirements, thermal constraints and crew participation. Environmental compatibility among the instruments on a given payload pallet or free flyer requires consideration of many contaminants like scattered light, exhaust gases, condensable matter, radio noise, electric or magnetic fields, microgravity accelerations, and radiation.

3.1.1 Summary

The research topics considered to be a part of science and applications are in the following fields:

Space Environment	Plasma Physics Atmospheric Sciences Magnetosphere Ionosphere
Astrophysics	Stellar Astronomy Galactic Astronomy

Earth Environment	Meteorology Climatology Geology Planetary Astronomy Solar Observations	Oceanography Land Utilization Episodic Events Cosmic Rays General Relatively
Life Sciences	Medicine Zoology Botany Microbiology Exobiology	
Materials Sciences	Pharmaceuticals Semiconductors	

The objectives of research in these areas are as varied as the subject matter. The overriding goal of Space Environment studies is to understand solar-terrestrial interactions that affect our terrestrial environment. In astrophysics the objective is to interpret the universe in terms of physical principles. Global monitoring of surface conditions that directly affect life on Earth is the goal of Earth Environment applications research. The principal goal of life sciences research is to improve man's ability to live in space and to use the response of living organisms to weightlessness as a means of gaining more understanding of biology and medicine. In materials research, the objective is to create purer products by avoiding gravitational separation. Specific research objectives in these diverse subjects are described in more detail in the following subsections (3.1.2 to 3.1.6).

The Space Station offers new capabilities for science investigations in space. The size of the facility permits much larger sensor systems to be constructed than have been practical heretofore. Availability of astronauts to perform construction, service the instrumentation, and closely supervise operation permits much more complex systems to be devised. Their ability to reconfigure modular hardware components, interrogate measurements and observations, and modify on-board software affords a broader scope to research objectives. Since the Station will remain in orbit permanently and be serviced regularly by Space Shuttle flights, there is opportunity for long duration experiments and programmed modifications.

The crew of the Station will be large enough to allow mission specialists to become intimately familiar with the experiments. Procedures can be modified to meet changing needs taking advantage of instrumentation potentials to perform unplanned measurements. Much more on-board data processing will be performed by mission specialists as computational systems become more sophisticated. Much of the repetitious and redundant data that would not ever be analyzed can be "left in space;" only baseline measurements and anomalies or abnormalities will need to be telemetered and recorded. In general, mission

specialists will be better able to take advantage of the learning curve through prolonged use of the equipment, and many experiments will benefit from their suggestions for improvements. Such familiarity with the experiments can potentially lead to unexpected discoveries (scientific serendipity).

Selection of experiments for early Space Station payloads is based on a number of factors. Our preliminary choices have been clustered according to similar scientific objectives, common pointing directions, necessity for a subsatellite (microgravity, contamination), need for regular service, close supervision, and special constraints like large size or high power. These groupings adequately incorporated most of the major instruments that are planned or have been suggested. Launch dates for payloads were selected on the basis of our understanding about their present level of development and subjective assignment of relative scientific merit.

When the request for proposals for Space Station experiments is issued, however, NASA should anticipate a large response including more diverse instruments from the scientific community. Then a subjective selection process will not be so easy to justify. A more objective method of payload prioritization and budget distribution is needed.

Clearly objectivity cannot be perfectly administered, but there exists a decision making tool that can assist significantly. Prioritization of experiments within each of the various classes of payloads (e.g., astrophysics, earth observations) might be achieved by the linear integer programming algorithm discussed in Section 3.1.1.4 and its Appendix in Volume 7-1. The method "picks" experiments by maximizing the "scientific value" of the payload experiments subject to constraints like cost, weight, power, and data management. Each experiment is subdivided into multiple options corresponding to different levels of sophistication. Each option of every experiment in the class is evaluated by a "Delphi" committee to determine its relative scientific value. The method has been applied to illustrative cases. Insofar as the average "scientific value" of each option, as determined by the "oracles," is relatively objective, the method provides NASA with reasonably objective technique to assist in the selection of payloads.

In addition to the variety of experiment classes that will be proposed by principal investigators, there should be general laboratories on board the Space Station. Such facilities would provide a shirtsleeve environment for mission specialists to test systems, calibrate sources, and repair or modify experiments. The laboratories should provide sophisticated instrumentation for a wide-range of special projects in physics and biology

such as: optics, electronics, mechanics, thermodynamics, medicine, chemical analysis and microanalysis. The instrumentation would be selected to complement the objectives of research payloads.

The need for special environments by many science and applications experiments impose certain constraints on the Space Station. Some classes of optics experiments are so sensitive to contamination by condensable matter that they must operate from a free-flying (maneuverable, recoverable) subsatellite; other experiments must avoid the large plasma perturbation generated by the Space Station structure. Thus, a key requirement will be the ability to launch and recover subsatellites in a benign environment. Many larger optical and radio experiments will operate or be constructed (or erected) at the Station. These necessitate external pallet mounts where power, mechanical controls, and astronaut extravehicular activity can be accommodated. Many experiments that require continuous attention will be permanently mounted on external booms around the Station exterior. Their scientific missions and environmental susceptibilities (e.g., scattered light, vapor condensation, thermodynamics, electromagnetic fields) will constrain the Station architecture and orientation. A number of other instruments require very accurate pointing, both relative and absolute.

Several experiments in fluid physics, life sciences, and materials sciences, require large laboratories inside the Station. Most of these are spaceborne to obtain a "zero-gravity" condition. Crew activity and Station rotations may be curtailed during some experiments that require micro-g accelerations. Life sciences experiments will need isolation to avoid contamination by toxic or biological matter. The life and material sciences experiments are apt to require special temperature, humidity, and air flow controls.

Common requirements for nearly all experiments include calibration, power switching, thermal control, and data handling. Integration of these foregoing physical requirements with an operational timeline for measurements and data processing is a challenging task.

3.1.1.1 Advantages of Space Station

The Space Station will be the first manned spacecraft that has sufficient resources, flexibility, and duration to allow on-site innovations with a variety of sophisticated scientific equipment. The size of the station will permit very large and massive systems to be assembled. Although still limited, electrical power will be more abundant. There will be more mission specialists available for longer service periods at the Station to supervise and modify operations. The goals of the principal investigators can be more easily achieved as the specialists attain surrogate status through deeper involvement with individual experiments. Many experiments will become evolutionary in nature due to the opportunity for extended operations over many months or years.

Currently, many of the experiments considered for use on the Space Station involve apparatus constructed on the ground and transported to the Space Station for deployment or assembly. Traditionally, one of the principal functions of an earth-based laboratory has been to provide a location equipped with a general array of equipment to test concepts and construct prototype equipment. In the case of the Space Station, the inclusion of a standard complement of instruments could provide data for current observation programs or other experiments and at the same time, serve as a limited testbed for new concepts which could not easily be tested in an earth-based environment. Operational guidelines for the Space Station should be structured to permit as much latitude of activity as possible within the limits of primary mission and safety requirements. Similarly, the provision of a limited construction capability might provide the ability to develop structures suitable to the Space Station environment but too fragile to survive launch and delivery.

If this style of space experimentation is to involve the education of graduate students, their participation should encompass the planning, design, data collection and analysis phases of research projects. Since graduate student involvement with a thesis project typically extends over a two to four year time period, the timeline for some experimental activities should fit within this time frame. Currently, most of the experiments considered for deployment by Shuttle are selected and constrained to specific objectives as long as 6 to 8 years before they are flown. Reducing this time span would open up participation to both students and a larger cross section of the scientific community.

Since the experimental facilities on board the station will be retained in orbit for long periods, they will become a national resource for the research community. Our present

National laboratories participate in programs encouraging visitors from other institutions to collaborate with laboratory personnel in research activities using the laboratory facilities. Similar programs should be set up for the Space Station users. This could become one of the chief advantages of the Station and motivate a large segment of the space science community to participate.

If a core of general instruments in a number of disciplines were included in the Space Station, experiments could be carried out during a much shorter time frame than would be the case for apparatus operated solely by one experimenter. One approach to supplying this core of instruments would be to incorporate selected individual instruments as semi-permanent portions of a core facility for multiple areas of research. To maximize the usefulness of potential core instruments, the instrument design should be reviewed by representatives of all research areas which require similar instrumentation in order to include features which would permit a broader base of use.

Regular servicing of the Station by the Shuttle will overcome a major obstacle in the present space science research programs. The problem facing present day laboratories is the rapid turnover of equipment needed to maintain a state-of-the-art facility. This turnover is particularly important in the area of imaging, image processing, and data processing facilities in general. Since these areas represent major portions of proposed Space Station activities, early consideration must be given to techniques for updating equipment without requiring major Space Station revisions. Particular attention should be given to those elements which might be fixed in the Space Station during construction and be difficult to modify at a later time. An example might be the inclusion of excess data bus capacity in the basic structure to permit future transmission capability expansion.

3.1.1.2 The Gordian Knot

In undertaking long-term planning for the Space Station, NASA must decide how best to involve potential and actual users of the Space Station. The scientific users are a particularly complex group because they belong to a variety of different kinds of institutions but almost invariably regard their experiments as highly personal creations.

The process of getting science or applications experiments approved and integrated into large multidisciplinary spacecraft like the Shuttle and Spacelab has been overly difficult in our opinion. The process may be likened to the mythical Gordian knot. Unraveling the red tape that ties the principal investigators to NASA procedures requires an enormous amount of nontechnical energy. The advent of mission specialists has brought another dimension of integration into the picture. The linkages are illustrated schematically in Figure 3.1.1-1 2 pages following. If the Space Station is to serve the research community effectively, someone must sever the procedural redtape much as Alexander cut the Gordian knot.

The Shuttle era has been frustrating for many space scientists, whether involved or not in programs that use the Shuttle. Four circumstances have mainly caused this:

1) Emphasis on Shuttle engineering has drawn support away from scientific programs. Support for science payloads on the Shuttle has diminished even though costs of experiments are much greater due to delayed launches and more complex integration procedures. Non-Shuttle research has been curtailed, too. The planetary exploration program appears to be the most affected.
2) In the 1970's Shuttle-based science was promoted very strongly by NASA. Investigators were invited to propose; working groups were formed and their requirements for Shuttle design were sought. There is a perception that in spite of various Phase A and B study reviews, the scientists had little impact on Shuttle design. To put it extremely, advocacy was wanted, not advice.
3) A part of the encouragement offered to propose experiments for Shuttle was assurance that it would be easy, quick and cheap to carry out these experiments. This has not proven to be true. The time between proposal and flight can be 6-8 years. During this interval an experiment may be rigidly controlled while knowledge changes. Documentation and conformance to awkward interface requirements drives costs upwards.
4) It has proven difficult for many approved experimenters to learn how to use the Shuttle, and this is doubtless also the case for users of other sorts. Division of responsibility between several NASA centers and lack of a training program for users has made it difficult to learn how to interface with Shuttle. It is likely that some potential users have been put off by this problem.

One consequence of the long development time for Shuttle and Spacelab is that the data handling system is not very powerful. The rapid pace of microprocessor development has made it possible to do a great deal more on-board data analysis in a seven-day mission than

the installed equipment will allow. Consequently, many experiments for Spacelab are being designed with a large amount of computing power as part of them bypassing the Spacelab system.

It will be important for NASA to avoid these difficulties in the Space Station program, especially if advocacy by potential users is sought. We offer the following suggestions for interacting with potential scientist-users:

- NASA should continue its commitment to support a broad range of scientific applications and technological research including that which exploits the Shuttle:
  - For the health of the Nation's technology;
  - To promote education in the space sciences and engineering disciplines.
- Starting now, the potential user community should be kept informed of status and plans. It would be very appropriate for NASA to publish a brief report in Summer 1983, describing the conclusions of the eight study contractors.
- Presumably user working groups will be formed within the next two years. These groups should be fully apprised of development plans for the Station, relative weights given to different classes of user, etc. If the user groups are asked to provide input to the design, be sure that these are obtained early enough to really affect the design. Make sure that the working groups are informed of the effect they have.
- Try to make the case for man in space clear.
- Do not solicit actual experiments prematurely. In making a selection do not prematurely freeze the hardware details.
- It is often advantageous to have a staff member at a cognizant NASA center on each investigator team. Perhaps it could be made a requirement. Policy on this topic should be established during solicitation for proposals, not later during evaluation.
- Make clear the investigators' and NASA's rights to data and to use of delivered equipment.
- Wherever project management and ultimately operational management of the Station is located, the contractor who builds it will have the most detailed engineering knowledge. This contractor should operate an interfacing and operations training center for users, beginning during the design phase. This would include mock-ups and simulators of the data system and other facilities that might be employed by a user. Separate programs could be offered for operating crew.

In order to provide the best possible data processing services, three approaches are possible:

- Wait to the last possible time to "freeze" the data handling equipment design. Once done, stick with that and force installed experiments to use it. Minimize the amount of computer equipment incorporated in each experiment to reduce cost.
- Install a large number of high-speed data busses, coaxial or fiber optics, and count on upgrading the computing equipment every few years using the same bus structure and hardware.

- Accept the fact that users will want to provide their own microprocessors. Provide help and flexibility in interfacing with users but do not provide central, installed computing equipment.

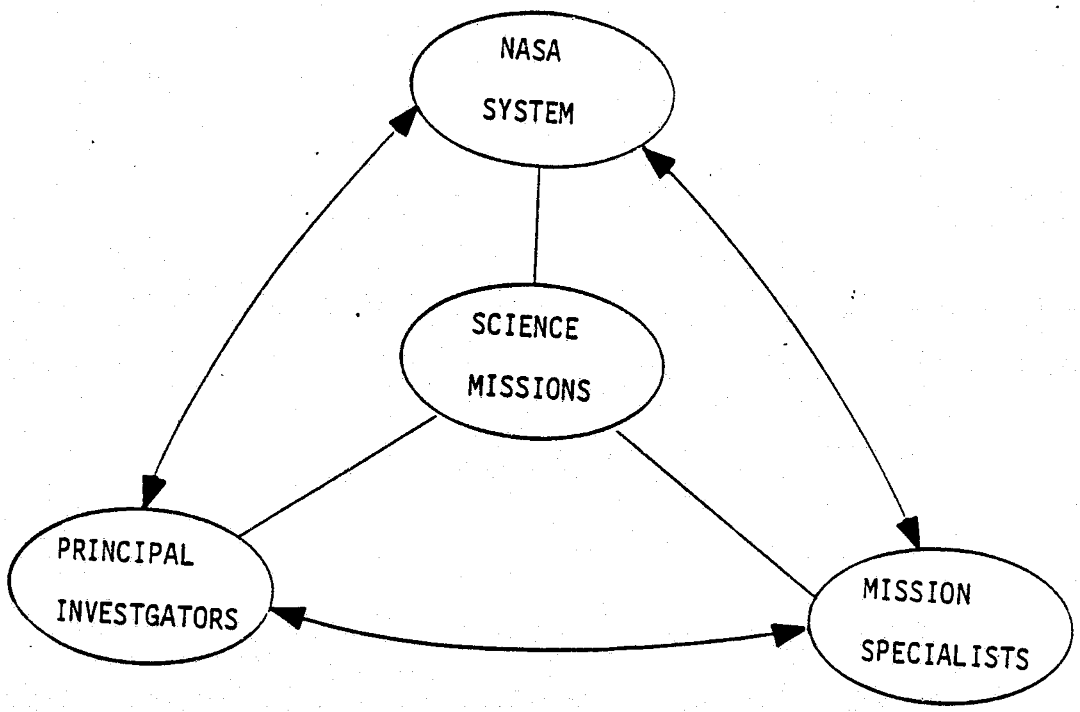

Figure 3.1.1-1. The Gordian Knot

3.1.1.3 Proposed Experiments

In order to canvas as broad a cross section of the science and applications user community as possible, letters of inquiry were sent to a large segment of the community. Our solicitation provided a brief description of the Space Station concept and a NASA User Data Form. With assistance of Science Applications Inc., and the Environmental Research Institute of Michigan, address lists of potential users — past, present, and future — were compiled in Space Environment and Life Sciences areas. The lists are provided in Volume 7-1.

The result of this polling was a large collection of user data forms. Several new experiments emerged and many older well-established concepts were reported. The

collection of forms is also included in Volume 7-1. They provided key input data for our summary tables presented in subsections 3.1.2-5. Of course, much of the tabular data came from the published literature as well. Bibliographies of this material are also found in Volume 7-1.

In addition to the user data forms from about 20% of those polled, we received many letters both pro and con concerning the merits of a Space Station for space science research. This correspondence is collected in Volume 7-1 as a potential resource for future studies.

3.1.1.4 Mission Selection Criteria

We are now embarking on a new era of space science research where large vehicles like the Shuttles and Space Stations carry multidisciplinary payloads. Their accommodations allow a great many instruments to fly together. Proposal evaluation and payload selection will become much more complex due to the increased number of submissions and the diversity of subject matter.

Many factors must be considered in the selection and integration of scientific experiments for spacecraft payloads. Foremost is the relative merit of the technical objective - is it worthwhile to do? Nearly as critical is the ability of the proposer to accomplish the objective - what is the track record of the proposer and his/her institution? Linked to these two is the question of credibility of cost estimates and other physical characteristics - are they realistic for the task? Collectively these subjective considerations are lumped together as scientific value or merit for the experiment.

The physical quantities that characterize an experiment also influence its desirability. Among them are cost, power, weight, data processing, telemetry, crew involvement, volume, and assembly time. Since these resources for a mission/payload are finite, the sums of these quantities for a selected group of experiments in a payload are constrained by prescribed limits.

This selection process can be expressed as a mathematical procedure wherein the scientific value of the payload is maximized subject to constraining conditions on the physical characteristics. Principal investigators would supply a set of physical characteristics for each level of complexity in their experiment. The more subjective scientific value would have to be determined by "nonvested experts," perhaps through a "Delphi committee", a

group of independent "oracles". The algorithm for selection has been developed and applied to illustrative cases as shown in Volume 7-1.

This selection tool does not lead to a unique, rigorous answer. In fact, there are usually families of solutions for a given set of constraints and scientific values. It is really a guidance tool to aid management in making a final decision.

The method provides management with a procedure to perform "what if" variations. The effects of changing parameters can be explored. Coupling conditions can be introduced to make two experiments better than their individual sum. Finally the technique establishes a quantitative basis for examining the incremental aspects of payload selection. As the cost constraint is relaxed, for example, there are circumstances where scientific value increases rapidly and others where it plateaus. Finding and operating at a knee in this relationship would assure a higher return on investment.

3.1.1.5 Space Station Requirements

Most of the Science and Applications experiments require special environments in order to function properly. Environmental areas of concern include scattered light, condensable matter, radio noise, electric or magnetic fields, toxic and biological matter, microgravity, and radiation. The Space Station is not an appropriate location for operation of many science instruments due to their low tolerance levels for these contaminants. However, the Station will provide a vital link in the science investigations by offering a staging area for launch, refurbishment, and control of large instruments and pallets housing groups of smaller instruments. Some experiments will be attached to the Station but many will have to operate on free-flying subsatellites.

Configuring the Space Station to handle more science experiments is impractical. Its size produces plasma distortions that are unnatural. The skin of the vehicle will outgas relatively fast but cabin atmosphere leakage is a continuous source of unnatural gas contamination. Water dumps and thruster exhaust are particularly obnoxious for optical experiments and must be avoided by recycling water and employing reaction wheels for orientation maneuvers. Stray light emission caused by diffuse reflection of sunlight and ram-ion interactions on forward surfaces may interfere with optical experiments. Depending on power, switching, and transmission systems, radio noise and electric, or magnetic fields may degrade with field experiments.

Usually these characteristics cannot be designed away to the satisfaction of instrument requirements. Consequently, an important provision of Space Station will be its ability to serve as a staging area. During such periods harmful emissions need to be suppressed or protective measures taken with sensors.

There are some less sensitive instruments that can operate on external mounts around the Space Station and, of course, internal laboratories will be located on-board. These external instruments require mounts that allow independent pointing and tracking. The internal labs are in space principally to take advantage of microgravity conditions so major accelerations of the Station should be avoided during experiments. Both external and internal experiments are expected to have rigorous thermal requirements that will impact design constraints.

Space Station missions of all kinds are expected to require long periods of operation and appreciable computations. One objective of the Station is offer a facility where instruments can function intermittently or continuously for months or years. Crew availability for handling such a time demand must be carefully scheduled. During dormant periods some provision for warehousing the experiments would be desirable. A "workshop" for repair or refurbishment of instruments inside the Station is anticipated.

The data stream from these experiments will be fed through the Station for preliminary processing. Large storage systems and parallel processors will be needed. Mission specialists cannot be expected to interrogate all of this data; some automatic screening algorithms will be essential to identify interesting anomalies for special attention by the crew. Rather than relying on telemetry channels to ground-based scientists, much of the data could be transported to the ground by Shuttle return flights using bit storage devices (tapes, disks) or high-density film.

Since many subsatellites will be operating near the Station over its lifetime, there is a major requirement for docking and tracking facilities. Hopefully, these functions will be largely automated by the time a Station is in operation. But the crew will have to monitor the systems regularly. Design of these facilities for efficient operation and minimum interference with experiments at the Station or on subsatellites is essential. Safety and protection of instruments are of paramount importance.

3.1.2 Space Environment

The space environment is comprised of the sun, the interplanetary medium, the magnetosphere, the ionosphere, and the upper and lower neutral atmosphere. These regions are coupled to each other such that varying solar activity affects the upper atmosphere and all regions between. The linkage between the upper and lower atmosphere is not well established and remains difficult to isolate because direct insolation and meteorological effects obscure the processes.

3.1.2.1 Scientific Objectives

Understanding the fundamental mechanisms that control the physical processes in this plasma and atmosphere is the primary scientific objective of space environment research. Spacecraft experiments have been flown for two decades building a quantitative description of the solar-terrestrial morphology. Much has been learned about cause and effect relationships but the transport processes are difficult to quantify.

The Space Station would provide the means to operate a larger and more complete set of experiments for investigation of solar-terrestrial physics. Several key objectives would be targeted for Space Station research:

1) Relationship of intrinsic solar properties to solar activity and particulate and radiative emission using solar instruments on the Station and an interplanetary satellite.
2) Particle acceleration and transport in the magnetosphere by combining the solar instruments and interplanetary satellite with in situ instruments and one or more magnetospheric satellites.
3) Field and particle links between magnetospheric effects and ionospheric currents and plasma using electron and ion beams, chemical releases, magnetometers, a topside radio sounder, and magnetospheric satellites.
4) Relationship of solar and magnetospheric effects to the neutral atmosphere including thermospheric dynamics and mesospheric chemistry by combining solar instruments and atmospheric instruments with cloud observations and ground measurements.
5) The role of wave-particle-plasma interactions in transport and coupling in the magnetosphere and ionosphere using electron injectors, wave injectors, chemical releases, and diagnostic packages on maneuverable subsatellites.

3.1.2.2 Potential Instruments

Instruments for Space Environment research fall into three classes: remote sensing, in situ detectors, and active experiments. Some phenomena must be observed remotely, such as variations in the solar photosphere, larger solar cloud cover in the atmosphere, upper atmosphere and auroral light emission, or radio emissions from the sun. Local detectors measure the electromagnetic field, particle velocity distributions, neutral atmosphere density, mass distribution, etc. These techniques are passive, and only their sampling rates can be varied.

Active experiments, are truly experimental in that the natural environment is altered and then observations are made. Tracer experiments employ a minimal perturbation, e.g., radar and lidar to measure plasma and neutral properties, electron beams and chemicals to sense quasi-static electric and magnetic fields. True perturbation experiments use large mass releases or inject electromagnetic waves or charged particles at high power. Here, naturally occurring effects are reproduced in a controlled manner on a scale that can be readily measured.

During the last two decades many solar-terrestrial instruments have been devised, built, flown, and revised so that a cadre of relatively standard techniques are presently available. A representative list of key instruments is defined in Table 3.1.2-1; many others could be added.

The solar-terrestrial scientific community has operated their instrumentation principally on unmanned spacecraft. Consequently, very little thought has gone into space experiments where man is in the operational decision loop. Some of these experiments might be enhanced by the opportunity to deploy less automated, easily modifiable instrumentation, where mission specialists can take a more active part.

The operating characteristics for these instruments are estimated in Table 3.1.2-2. The alpha code used for many of the operational conditions is defined in Table 3.1.2-3. This code is also applicable to the tables in following subsections.

3.1.2.3 Proposed Payloads

It should be obvious that Space Station alone, no matter how well equipped, cannot support a comprehensive solar-terrestrial physics program. To make in situ measurements in the

TABLE 3.1.2-1. SPACE PLASMA PHYSICS POTENTIAL INSTRUMENTS

201	Particle Accelerator. Accelerates electrons and any of several ion species to energies 100 eV to 100 keV. Currents to several amperes. Pulse patterns. Also emits plasma to alter local medium.
202	Wave Injection. Transmitter 1 Hz to 30 NHz. Power to several kW. Broadband receiver.
203	Energetic Particle Detector. Electron velocity distribution 5 eV to 200 keV. Ion velocity distribution 5 eV to 200 keV. (Ion mass spectrum, see 208).
204	Plasma Diagnostics Instruments. Plasma density and fluctuations. Plasma electron velocity distribution (temperature) to 5 eV.
205	ULF/VLF/HF Antenna. Variable length antennas to transmit/receive over the frequency range 1 Hz to 30 MHz. Loop antennas to receive/respond to magnetic vector.
206	Chemical Release Canisters. Thermite and other chemical reactions release Li, Cs, Ba, O, SF_6 and other tracer/perturbing chemicals.
207	Video Cameras. High sensitivity imager senses UV, Vis and IR emitted from aurora, airglow, chemical releases. Sensitivity 1kR. Spatial resolution of 10m.
208	Mass Spectrometer. Neutral mass spectrograph and ion mass spectrograph. Measure majority and trace species both naturally occurring and injected as tracers in the magnetosphere. Neutral density gauge. Ionization type gauge measures total density.
209	Laser/Lidar (actually an atmospheric instrument). Two or three wavelengths 0.33 to 1.5 m. Transmit 20W through 1-m diameter optics; receive scattered return from aerosols and clouds in lower atmosphere.
210	X-ray Imager. Image 10 keV to 500 keV x-rays produced as bremsstrahlung in upper atmosphere by precipitating electrons.
211	Imaging UV, Vis, IR Spectrometer (atmospheric instrument). Image with 1 km resolution at wavelength 200 A to 12,000 A. Wavelength resolution of 0.5 A. Measures distribution of species and states in atmosphere.
212	Magnetic Confinement Apparatus. Magnetic Coils generate field of up to 5 gauss in region 5-m diameter by 20-m length. Used in conjunction with particle accelerator for beam plasma studies. Fusion research, if implemented, would require a much stronger field.
213	Retro-Reflector. Mounted on a subsatellite the reflector would return beam from a tunable laser to a receiver on Space Station. Intervening atmosphere acts as absorption cell.
214	Backscatter Radar. Coherent scatter radar measures ion drift velocity 10 m/s, 1 to 500 MHz.

TABLE 3.1.2-1. SPACE PLASMA PHYSICS (CONT.)

215 UV, Vis, IR Telescope. Optical instruments to observe and measure distant natural phenomena such as airglow and aurora and local active perturbation effects due to chemical releases or particle beam injections.

216 ULF/VLF/HF Receivers (new instrument). Receive over range 1 Hz to 30 Hz. Phase coherence of $\underline{B}$ and $\underline{E}$. Polarization vector and Pointing vector.

217 Static Field Detector (new instrument). Magnetometer (fluxgate): measures static vector field. Electric field double probes: measures static vector field.

TABLE 3.1.2-2. SCIENCE AND APPLICATIONS INSTRUMENTS

SPACE SCIENCE
MAGNETOSPHERE, IONOSPHERE, ATMOSPHERE

CODE	NAME	COST $M	AVERAGE POWER 1 kW	LAUNCH WEIGHT kgm	LAUNCH VOLUME m^3	DATA PROCESS 2	TELEMETRY LEO RATE 3	TELEMETRY LEO INCLIN 4	POINTING DIRECT 5
201	PART ACCEL	20	10	5800	4	M	L	HL	M
202	WAVE INJECT	15	2	300	3	H	L	HL	M,A
203	PLASMA E SPECT	4	0.2	10	0.2	M	L	HL	A
204	PLASMA DIAG	6	0.2	20	0.4	H	M	HL,PL	A
205	ULF/VLF REC	3	0.5	200	20	M	L	PL	M
206	CHEM REL CANS	7	0.1	1000	12	L	M	HL	M
207	VIDEO CAMERAS	1	1	50	1	H	H	A	A
208	ION MASS SPEC	4	0.1	300	2	L	L	HL	A
209	IR LIDAR (WIND)	50	5	2000	4	M	L	HL,PL	E
210	VIS LIDAR (TEMP)	10	5	500	2	M	L	HL,PL	E
211	IMAG UV-IR SPECT	15	1	200	3	H	M	HL,PL	E
212	UV-IR TELESCOPE	12	1	300	4	M	L	A	E
213	XRAY TEL (ATMOS)	10	0.3	200	3	L	LHL,PL	A	E
214	MAG CONFINE LAB	10	5	1000	4	M	L	A	M
215	RETRO REFL TRAKR	20	1	1000	10	L	L	A	A
216	BACKSCAT RADAR	30	100	2000	200	H	M	HL	A

*See Table 3.1.2-3 for entry code.

TABLE 3.1.2-2. SCIENCE AND APPLICATIONS INSTRUMENTS

SPACE SCIENCE
MAGNETOSPHERE, IONOSPHERE, ATMOSPHERE (CON'T)

CODE	NAME	POINTING STABIL 6	VEHICLE SITE 7	ENVIRON SUSCEPT 8	ENVIRON PERTURB 9	SETUP TIME hrs	INSTRUMENT OPERATION hrs/dy	INSTRUMENT OPERATION dys/yr	CREW INVOLVE mndys/yr
201	PART ACCEL	M	SS	EMF	R,E	3	2	32	8
202	WAVE INJECT	M	SS,FF	RN	R,E	6	2	32	8
203	PLASMA E SPECT	N	FF	EMF	N	0	1	365	4
204	PLASMA DIAG	N	FF	EMF	N	0	1	365	12
205	ULF/VLF REC	M	FF	RN, EMF	N	16	4	200	8
206	CHEM REL CANS	M	SS	N	G	0	6	40	30
207	VIDEO CAMERAS	M	SS	N	G	0	4	365	365
208	ION MASS SPEC	N	FF	CM	N	0	2	365	0
209	IR LIDAR (WIND)	VG	SS,FF	CM,LT	L	0	6	365	270
210	VIS LIDAR (TEMP)	VG	SS,FF	CM,LT	L	0	4	365	180
211	IMAG UV-IR SPECT	VG	SS,FF	CM,LT	N	6	4	120	60
212	UV-IR TELESCOPE	VG	SS,FF	CM,LT	N	0	2	100	25
213	XRAY TEL (ATMOS)	M	SS	N	N	0	8	40	40
214	MAG CONFINE LAB	M	SS,FF	EMF	M	4	8	20	30
215	RETRO REFL TRAKR	M	SS,FF	LT	N	8	1	64	9
216	BACKSCAT RADAR	M	SS,FF	EMF	R,E	80	4	60	40

*See Table 3.1.2-3 for entry code.

TABLE 3.1.2-3. SCIENCE AND APPLICATIONS INSTRUMENTS

TABULAR ENTRY CODE

1	AVERAGE POWER		INTEGRATED AVERAGE POWER DURING NORMAL OPERATION; NEGLECTS PEAKING REQUIREMENTS
2	DATA PROCESSING	L	LOW, kbps
		M	MEDIUM, kbps-Mbps
		H	HIGH, Mbps
3	TELEMETRY RATE	L	LOW, kbps
		M	MEDIUM, kbps-Mbps
		H	HIGH, Mbps
4	LEO INCLINATON (Low Earth Orbit)	EQ	EQUATORIAL (NEAR 0)
		LL	LOW LATITUDE (AROUND 29)
		HL	HIGH LATITUDE (ABOVE 58)
		PL	POLAR LATITUDE (NEAR 90)
		SS	SUN SYNCHRONOUS (90)
		A	ANY LATITUDE
5	POINTING DIRECTION	E	EARTHWARD
		I	INERTIAL (LONG INTEGRATION TIME)
		M	LOCAL MAGNETIC FIELD ALIGNMENT
		S	SUNWARD
		A	ANY DIRECTION
6	POINTING STABILITY	M	MODERATE (ABOVE 1 DEG)
		G	GOOD (1 DEG TO 5 SEC)
		VG	VERY GOOD (1 SEC to 5 SEC)
		EG	EXTREMELY GOOD (BELOW 1 SEC)
		N	NONE
7	VEHICLE SITE	FF	FREE LAYER SPACECRAFT
		SS	SPACE STATION FACILITY
		TD	TETHERED SUBSATELLITE
		A	ANY VEHICLE
8	ENVIRONMENT SUSCEPTIBILITY	LT	SCATTERED LIGHT
		CM	CONDENSABLE MATTER
		RN	RADIO NOISE
		EMF	ELECTRIC OR MAGNETIC FIELDS
		TM	TOXICOLOGICAL MATTER
		BM	BIOLOGICAL MATTER
		N	NONE
		MG	MICROGRAVITY
		RD	RADIATION
9	ENVIRONMENT PERTURBATION	G	EXHAUSTS COLD GAS
		N2	LIQUID NITROGEN VENTING
		HE	LIQUID HELIUM VENTING
		RN	RADIO NOISE
		E	ELECTRIC FIELDS
		M	MAGNETIC FIELDS
		L	BRIGHT LIGHT SOURCE
		N	NONE

magnetosphere and solar wind, several spacecraft are needed, such as the complement designed for OPEN (equatorial, magnetotail, polar, interplanetary). Similarly, ground-based, balloon and rocketborne sensors will be required for lower and middle atmosphere measurements. Even for in situ measurements in low earth orbit, Space Station is not particularly advantageous because its large size produces local perturbations that badly distort the natural plasma environment.

Consequently, the experimental system must include facilities for remote instrument carriers as well as platforms attached to the Space Station. A comprehensive system would include the following:

Manned Space Station carries:

- Remote sensors
  - of sun
  - of atmosphere
- Active stimulation & active sensors
  - e-m wave injectors
  - charged particle injectors
  - plasma injectors
  - lidar
  - radar
- Some in situ sensors
  - energetic particles
  - plasma
  - neutral atmosphere
  - electromagnetic field

  The latter three may experience local contamination.
- Means to deploy, control and recover a maneuverable subsatellite.
- Possibly means to deploy chemical release canisters and small nonrecoverable sensor packages (multiprobes).
- Possibly means to deploy a tethered subsatellite.

Maneuverable Subsatellite carries:

- Complete set of in situ sensors to study the natural environment.
- Receivers/sensors of perturbations generated at Space Station.
- Retro-reflector for laser/lidar.
- Perhaps means to deploy chemical release canisters.

Tethered Subsatellite carries:

- o Instruments to sample at 90-150 km altitude.
- o Conducting surface for electrodynamic experiments.

Multiprobe Subsatellites carry:

- o Sets of in situ sensors to measure spatial gradients between their locations.

Space Science payloads are defined in Table 3.1.2-4 to illustrate some of the foregoing experimental packages. Payload characteristics are summarized in Table 3.1.2-5. The data in Table 3.1.2-2 has been incorporated into these payloads to provide input for the Manifesting Code discussed in Section 2.2 of this report.

3.1.2.4 Payload Requirements

Although many space environment experiments will necessarily operate from separate subsatellites, the Space Station can perform the duties of a command and control center for this research. Mission specialists will be intimately involved with operation (e.g., pointing, releasing canisters , data interrogation) of experiments mounted on the Station and also tending the active experiments on subsatellites. Coordination of simultaneous measurements of natural processes and active injections will require well-planned experimental operations. The Station will also carry facilities to reduce raw data and perform first-order interpretations.

Much of the active research will be conducted during special solar, atmospheric, or ionospheric conditions. These conditions will normally be sensed by instruments on-board the Station and require the crew to 1) initiate high data collection rates on subsatellites, 2) perform active experiments promptly, and 3) inform ground operations to initiate high data rates at other spacecraft and appropriate ground research centers.

Table 3.1.2-4. Proposed Space Environment Payloads

PAYLOAD CODE	PAYLOAD NAME	EXPERIMENT CODE	EXPERIMENT NAME
SP01	Space Science Subsatellites		Particle and field sensors to measure gradients and transport processes
SP02	Space Physics Pallet	201	Particle Accelerators
		211	Imaging UV-IR Spectrometer
		212	UV-IR Telescope
		213	X-Ray Telescope
		214	Magnetic Confinement Lab
		215	Retro-Reflector Tracker
SP03	Upper Atmosphere Research Package		H_2 Occultation Experiment
			Temperature and Wind
			Cryo-Limb Etalon Spectrometers
			Stratospheric Sounder
			High Resolution Doppler Imager
			UV Solar Sensor
			IR Solar Radiometer

Table 3.1.2-5. Space Environment Astrophysics and Space Environment Configuration Requirements

SCIENCE AND APPLICATIONS MISSIONS	ORBIT		PROGRAM				SIZE/ WEIGHT		INTERFACE										OPERATIONS			ENVIRONMENT			
	INCLINATION (DEGREES)	ALTITUDE (KM) - (A) ANY, (L) LOW	SCHEDULE (YEAR)	NUMBER OF FLIGHTS	DURATION (MONTHS)	UPPER STAGE	VOLUME (M^3)	WEIGHT (KG)	POWER AV./PEAK (KW)	HEAT REJECTION MIN/MAX	ORIENTATION - (I) (S) (E) (A) ANY	POINTING/STAB ARC SEC/ARC-SEC/SEC	DATA	BERTHING PORT	INTERNAL	EXTERNAL	S.S. MANIPULATOR	PLATFORM (P) HANGAR (H)	IVA	EVA	FREE FLYER SERVICING (S), REMOTE (R)	LOW CONTAMINATION	"0" G	MICRO METEROID PROTECTION	RADIATION PROTECTION
S001 EARTH OBSERVATION PALLET	98	L	93/05	1			2.5		3.5		E								X	X					
S002 SYNTH APERTURE RADAR	98	L	95/05	1			1		10		E								X	X					
S003 HETERODYNING CO_2 LIDAR	98	L					1		1		E								X	X					
S004 UPPER ATMOSPHERE RES PKG.	98	L	97/05	1			0.9		2.16		E								X	X					
SP01 SPACE SCIENCE SUBSATELLITE	98	L	92/99	2							A									X					
SP02 SPACE PHYSICS PALLET	98	L	93/05	2			2		0.4		E								X	X					
SA01 VLBI/COSMIC RAY PKG	98	L	92/05	1			1		2		A								X	X					
SA02 TELESCOPE CLUSTER	29	L	91/03	2			2		4		A								X	X					
SA03 ASTROPHYSICS TREE FLYER	29	L	93/05	2							A									X					
SA04 ASTROPHYSICS OBSERVATORIES	29	L	90/05	1							A									X					
SA05 LARGE RADIO TELESCOPE	29	L	00/05	1							A								X	X					

3.1.2.5 Crew Requirements

The majority of space environment crew tasks for the early space station will be of a laboratory technician nature. The tasks will involve the set-up, calibration, maintenance, modification, reconfiguration and repair of the space physics instrumentation. The duties will be primarily to carry out ground designed experiments.

Many of the phenomena of prime interest and value will be unscheduled (e.g., solar flares and resulting environmental effects, high altitude electrical storms.) Other unanticipated phenomena may be more important than ongoing research (e.g., high altitude lightning was discovered by Shuttle crews while on orbit). The mission specialists will need to make quick judgments of the relative value of different events and to quickly reconfigure apparatus as required to record the most important phenomena.

Not all of the data collected can be transmitted to ground in realtime. Therefore, the crew will need to screen the data and select which data will be transmitted immediately, which data will be transmitted or transported later, and which data will be discarded.

The early space station space environment personnel will need the following skills:

- Basic electronic engineering skills
- High level diagnostic and troubleshooting skills
- Aptitude for precise remote control operations
- EVA qualified
- Mechanical aptitude
- Intermediate training in space environment physics

As the station evolves and staffing levels increase, the scope of the space environment research will increase. The space station personnel will gain increased responsibility for designing and scheduling research. The crew will conduct at least preliminary analyses on much of the data collected. In later missions personnel will also need advanced training in the research being conducted.

3.1.3 Astrophysics

Astrophysics research encompasses components from a number of disciplines including:

1) High Energy Physics
   a) Stellar evolution
   b) Elemental abundance
   c) Stellar emission and energy generation processes
   d) Condensed matter (white dwarfs, neutron stars and black holes)
   e) Cosmic rays

2) Optical and Radio Astronomy
   a) Properties and motions of stars, planets, comets, asteroids
   b) Planetary systems (solar system and extra solar-system)
   c) Solar observations
   d) Interstellar dust, chemicals and plasma
   e) Astronomical formations (solar systems, stellar clusters, galaxies, galactic clusters)
   f) Unusual objects (black holes, quasars, pulsars)

3) General Relativity and Fundamental Physics
   a) Properties of unusual astronomical objects
   b) Tests of relativity theories
   c) Variation of physical constants
   d) Cosmology

4) Deep-Space Plasmas
   a) Non-terrestrial magnetospheres
   b) Acceleration of charged particles
   c) Non-thermal photon emission
   d) Galactic and stellar formation

Experimental research on these subjects relies principally on remote sensing instrumentation to gather data on the stellar and galactic processes of the universe. By operating from spacecraft most of the deleterious terrestrial surface effects can be avoided. The Space Station is especially attractive for astrophysics research because it provides an opportunity to conduct long term observations, to correlate observations from a number of instruments, and to search for and monitor transient events of astrophysical interest.

Because of the vast distances involved and consequent low signal strengths, many astrophysical measurements have low counting rates and poor statistics. Ground-based instrumentation is restricted further by interference caused by atmospheric conditions, the rotation of the earth and limitations on instrument size. Furthermore, the atmosphere is opaque to most radiation.

The Space Station environment offers potential solutions in all of these areas. Proper orbital choices can provide the potential for long term integration over selected portions of the sky. In addition, the correlation between instruments in complementary orbits or between space and ground-based units can provide the data needed for long baseline interferometric studies. The zero-gravity environment and Space Station facilities offers the opportunity to construct very large instruments (e.g., a large radio telescope) without the support structure and high mass required for a ground based installation.

3.1.3.1 Scientific Objectives

The following astrophysics research goals could be met through observations conducted from Space Station experiments or free-flying derivatives.

1) Definition of nuclear processes occurring in stars and verification of models predicting stellar evolution and elemental abundance.
2) Properties of condensed nuclear matter in stellar cores.
3) Understanding of the time history of the universe and processes leading to present universe phase space distribution.
4) Understanding of the physical processes taking place in regions of unusual energy emission (quasars, radio sources, etc.)
5) Tests of general relativity (e.g., gravity wave detection, solar oblateness)
6 Verification of theories of cosmological evolution (matter/anti-matter ratios, continuous expansion vs. oscillating universe)
7) Detection of extra-solar system planets

3.1.3.2 Potential Instruments

The instruments listed in Table 3.1.3-1 are presently under consideration or in development for astrophysical studies from space platforms. Their operational characteristics are summarized in Table 3.1.3-2; the entry code is listed in Table 3.1.2-3 above.

TABLE 3.1.3-1. ASTROPHYSICS POTENTIAL INSTRUMENTS

301 Infrared Telescope (SIRTF, IRTEL) - Perform imaging and spectroscopy for IR wavelengths. Measure infrared spectrum of and image astronomical objects such as new stars.

302 Interferometer (VLBI) - Radio telescopes timed in phase to permit high resolution using very long baseline interferometry. Detect and locate small angle radio sources or measure detailed structure of larger sources.

303 X-ray telescope (XTEL) - Imaging of x-rays in the range 200 Å to 30 kEv. Measurement of x-rays from galactic sources and the sun.

304 Gamma-ray Telescope (GAMTEL) - Measure gamma rays in the 10 keV to 10 MeV at a resolution of 1 are minute. Perform imaging and spectroscopy of astronomical objects.

305 Visible Telescope (OPTEL) - Make photoelectric measurements with one meter telescope in the visible. Observe nearby stars for evidence of planetary systems.

306 UV Telescope (UVTEL, STARLAB) - Image and measure ultraviolet spectrum from visible to x-ray region. Perform UV imaging and spectroscopy of astronomical objects.

307 High Resolution X-ray Spectrometer (HRXS) - Measure x-ray spectra from 200 Å to 30 keV. Observe elemental abundunces and excitation levels of stellar and interstellar sources.

308 Large Area Modular Array of Reflectors (LAMAR) - Light gathering system for study of faint objects in deep space.

310 Superconducting Magnet Spectrometer (SUPERMAG) - Ultra-high magnetic field for differentiation of energetic nuclei.

311 Heavy Cosmic Ray Nuclei Explorer (HNE) -Sensor materials (scintillators) that have heavy nuclei signatures.

312 Large Area Cosmic Ray Detector (LACRD) - Detect and record passage of high energy heavy nuclei cosmic rays. Look for occurrence of heavy nuclei in primary cosmic ray flux.

314 Radio Telescope (RADTEL) - Image radio sources in the millimeter wavelength range using a precision 30' dish. Measure cosmic radio sources alone and in conjunction with another instrument to form VLBI system.

315 Microwave Receiver (MRSA) - Measure discrete microwave emissions at 4.3, 10.65, 18.7, 21.0, and 36.5 GHz. Determine microwave power output of astronomical objects (also Earth Observations instrument).

316 Imaging Spectrometer (IMAGSPECT) - Measure spectral emission over 300 Å - 12,000 Å range. Determine emission spectra and elemental abundances of stellar and interstellar sources.

TABLE 3.1.3-1. ASTROPHYSICS POTENTIAL INSTRUMENTS (CONT.)

317 Gravity Wave Experiment (GRAVWAVE) - Measure coincident perturbations in large mass metal blocks caused by incident gravitational waves. Look for gravitational waves from astronomical objects.

318 Geophysical Fluid Flow Cell (GFFC)- Rotating multilayer fluid vessel to study planetary and stellar formation and structure.

319 Spectra of Cosmic Ray Nuclei (SCRN) - Fields and attenuation material and sensors in a telescope array to determine energy spectra and composition of cosmic ray nuclei.

320 Solar Optical Telescope (SOT) - A high resolution solar telescope with several interchangeable sensor modules to study solar surface phenomena.

TABLE 3.1.3-2. SPACE SCIENCE
ASTROPHYSICS
NUCLEAR PHYSICS, ASTRONOMY, SOLAR PHYSICS, RELATIVITY

CODE	NAME	COST $M	AVERAGE POWER 1 kW	LAUNCH WEIGHT kgm	LAUNCH VOLUME m^3	DATA PROCESS 2	TELEMETRY RATE 3	LEO INCLIN 4	POINTING DIRECT 5
301	IRTEL (SIRTF)	350	1.0	6500	144	M	L	LL	I
302	VLBI	50	1.0	350	8	M	L	HL	I
303	XTEL	100	2.0	5000	30	M	L	LL	I
304	GAMMATEL	30	0.5	1000	3	L	L	LL	I
305	OPTEL	10	0.1	400	3	L	L	LL	I
306	UVTEL (STARLAB)	80	2.2	1800	10	H	M	LL	I
307	HRXS	175	2.5	8000	60	H	M	LL	I
308	LAMAR	100	3	9300	60	L	L	LL	I
310	SUPERMAG	80	5	1500	4	M	L	HL	A
311	HNE	10	0.5	200	2	L	L	HL	A
312	LACRD	100	1.0	4000	30	L	L	HL	A
314	RADTEL	40	0.1	2000	3	L	L	LL	I
315	MRSA	20	0.2	80	2	L	L	LL	I
316	IMAGSPECT	25	0.2	500	3	L	L	LL	I
317	GRAVWAVE	30	0.3	2900	5	L	L	A	A
318	GFFC	15	0.5	110	2	L	L	A	A
319	SCRN	75	0.4	3000	8	L	L	HL	A
320	SOT	150	6.0	6600	85	H	M	ML	S

See Table 3.1.2-3 for Entry Code

TABLE 3.1.3-2. SPACE SCIENCE ASTROPHYSICS NUCLEAR PHYSICS, ASTRONOMY, SOLAR PHYSICS, RELATIVITY

CODE	NAME	POINTING STABIL 6	VEHICLE SITE 7	ENVIRON SUSCEPT 8	ENVIRON PERTURB 9	SETUP TIME hrs	INSTRUMENT OPERATION		CREW INVOVLE mndys/yr
							hrs/dy	dys/yr	
301	IRTEL (SIRTF)	G	FF,SS	LT,CM	HE	20	20	365	30
302	VLBI	G	SS,FF	RF	N	10	6	200	50
303	XTEL	VG	SS,FF	RD	N	0	24	365	10
304	GAMMATEL	VG	SS,FF	RD	N	0	24	365	5
305	OPTEL	VG	FF	LT,CM	N	8	24	365	20
306	UVTEL (STARLAB)	EG	FF	LT,CM	N	8	24	365	10
307	HRXS	EG	SS	RD	N	0	24	200	40
308	LAMAR	G	SS	N	G	40	24	365	60
310	SUPERMAG	N	SS	N	HE	0	24	365	10
311	HNE	N	SS	N	N	0	24	365	2
312	LACRD	N	FF,SS	N	N	5	24	365	10
314	RADTEL	VG	FF	RN, EMF	N	80	24	365	20
315	MRSA	VG	FF	RF	N	0	24	365	22
316	IMAGSPECT	EG	FF	LT,CM	N	8	24	365	20
317	GRAVWAVE	N	SS,FF	MG	N	2	24	365	5
318	GFFC	N	SS	MG	N	3	2	40	10
319	SCRN	N	SS,FF	N	G	1	24	365	5
320	SOT	VG	SS	CM	N	8	8	365	100

See Table 3.1.2-3 for Entry Code

3.1.3.3 Proposed Payloads

From this list of instruments, five payloads have been selected to illustrate the requirements astrophysics research will impose on Space Station operations. The instrument groups for each payload are tabulated in Table 3.1.3-3. Our selections were grouped according to perceived common observation targets, environmental considerations, and level of crew service. Payload characteristics are summarized in Table 3.1.2-5. These cases have been used in Section 4.0 for Manifesting Code inputs and determination of Mission Requirements.

3.1.3.4 Payload Requirements

Most of the astrophysical observations of distant objects require a high degree of pointing accuracy and a relatively long integration time to achieve acceptable counting statistics. The cosmic ray detection instruments, however, look for relatively unusual events with no well-defined source and are therefore not particularly sensitive to their pointing direction or to interference from other Space Station activities. The Telescope Cluster package requires very good pointing accuracy and will be susceptible to Space Station vibrations which might disturb its stability. Another potential problem will be electrical noise which might interfere with the sensitive detection electronics in this package. The same restrictions apply to the Free-Flyer package with the additional problem posed by the potential for the deposition of Space Station emissions on optical surfaces during refurbishment and sensor module changes.

3.1.3.5 Crew Requirements

Astrophysical research is generally preplanned and of relatively long durations. It generally does not require unscheduled reconfiguration of the research and equipment. The exceptions are solar observations, comets, and planetary observations. Generally, all of the data collected will be transmitted or transported to ground.

The space station astrophysics personnel will need the following skills:

- Basic electronic engineering skills
- High level diagnostic and trouble shooting skills
- Aptitude for very precise remote control operations
- EVA qualified
- Mechanical aptitude
- Basic training in astrophysics

TABLE 3.1.3-3. PROPOSED ASTROPHYSICS PAYLOADS

PAYLOAD CODE	PAYLOAD NAME	EXPERIMENTS CODE	EXPERIMENTS NAME
SA01	VLBI/Cosmic Ray Package	302	Very Long Baseline Interferometry
		311	Heavy Cosmic Ray Nuclei Exploric
		319	Cosmic Ray Composition and Energy Spectra
		312	Large Area Cosmic Ray Detector
SA02	Telescope Cluster	301	IR Telescope (SIRTF)
		303	X-Ray Telescope
		304	X-Ray Telescope
		307	X-Ray Spectrometer
SA03	Astrophysics Free Flyer	305	Optical Telescope
		306	UV Telescope (Starlab)
		314	Radiotelescope
		315	Microwave Receiver
		316	Imaging Spectrometer
SA04	Astrophysics Observations		Advanced X-Ray Astronomy Facility
			Gamma-Ray Observatory
SA05	Large Radio Telescope	002	30-meter aperture multiband radio telescope

3.1.4 Earth Environment

Observation of surface conditions on earth has been the principal noncommercial application of spacecraft. Optical and radio sensors will have increasingly important roles for remote assessment of weather, agriculture, and sea-state conditions. The advent of Space Stations will provide an important manned base for this instrumentation where in situ evaluation of measurements and modification of sensors can improve their information gathering ability. There are several experiments in fluid and solid physics that lead to better understanding of planetary formation and dynamics which will require an internal Space Station laboratory.

3.1.4.1 Technical Objectives

The overall objective is to provide more complete and accurate information about terrestrial conditions that affect local and global economics. Earth observations from space platforms provide vital measurements about food production, range land and forest management, geology particularly mineral exploration, prediction and assessment of man-made and natural disasters, hydrology, especially fresh water reserves in mountains, and sea-state conditions. Crop management will improve through increased knowledge of soil moisture, disease and infestation detection, and in crop producton estimates. Our mineral exploration will continue to be aided by highly selective multispectral panoramic imaging at several scales. Hazard warning and post-disaster assessment systems for catastrophic events such as earthquakes, severe storms, floods, forest fires and volcanoes will be valuable to the government and to commercial entities with large land holdings, such as in open ranges and forestry. Short-term weather forecasting and long-term climatic changes need extensive and continuous coverage of the global conditions. The shipping and fishing industries use ocean currents, sea ice distributions, and fishery movements in their operations.

There are many terrestrial processes that need scientific study in the zero-gravity environment of a space station where mission specialists are available to guide and control experiments. In planetary geophysical processes the areas to be investigated include fluid mechanics, soil mechanics, interactions between fluid-solid systems, and condensation or accretion. These experiments may be conducted under various combinations of gravity, pressure and space environments requiring a broad test matrix. The mechanics of low gravity flows have immediate application in the modeling of geophysical flows such as the earth's global atmospheric dynamics, cloud dynamics, and the processes that reshape the

landscape of the planets. Experiments in parameter ranges that are unattainable on earth may lead to discovery of new fluid dynamic phenomena. Some of the interesting flow regimes will include convecting or buoyancy-driven flows at low gravity with large thermal and/or concentration gradients, flows where the fluctuating gravitational force is large compared to its mean value, flows where surface tension and its gradient are dominant, and convection with phase changes. Erosion by liquids, gases or solids under various pressure conditions as well as cratering studies are included in this category. Studies of condensation, evaporation, sublimation, and accretion also will add to understanding the evoution of the planetary system.

3.1.4.2 Potential Instruments

The earth observations instruments provide a versatile collection of remote sensors capable of fulfilling all of the anticipated user requirements. The collection of planned or proposed instruments are summarized in Table 3.1.4-1 below.

Characteristics of these instruments are summarized in Table 3.1.4-2; see Table 3.1.2-2 for the tabular entry code.

The planetary geophysical processes laboratory in the space station could be as simple as an external mount for samples or as elaborate as a modern geophysical sciences laboratory found on earth. Some of the candidate instruments are:

1) Photographic Equipment: Used for qualitative studies of physical processes, the most important instrument will be a camera to record the phenomena for analysis be earthbound scientists.
2) Experimental Modules: Used to supply fluid cells of various shapes and fluid compositions for experiments including concentration distributions, fluxes, etc.
3) Measurement Apparatus: Used to measure fluid velocities, temperatures, densities, and concentrations.
4) Flume: Used to model erosion by liquids at low gravity.
5) Wind Tunnel: Used to model erosion by gases.
6) Rotating Table: Used to model the effects of rotation (Coriolis force) or to simulate low values of gravity.

TABLE 3.1.4-1. EARTH OBSERVATION INSTRUMENTS

401 Imaging Spectrometer: May be used for a variety of earth observations missions from agriculture to search and rescue providing spectral signatures in images with high resolution; the pointable feature allows the analyst to locate and maintain the same field of view.

402 Laser Ranger: Used to obtain very high accuracy altitude measurements, for example, for earthquake prediction.

403 Multispectral Scanner: A Landsat class multispectral sensor used for routine surface measurements continuing a data supply for existing remote sensing systems.

404 Synthetic Aperture Radar (SAR): An imaging high resolution (10-30 m) radar for all weather operation.

405 Lidar: Used to measure atmosphere temperature profiles and atmosphere constituents.

406 Camera Hi-Res: A bank of film cameras used to obtain multispectral images of the earth on film with no telemetry or recording data rate problems.

407 Scatterometer: Used for ocean measurement such as wave height, wind velocity.

408 Interferometer: Used to measure particle movement and winds in the various atmospheric layers.

409 Video Camera/Color Monitor: A conventional video system with camera, monitor, and tape recorder for general use by the operator.

410 Optical telescope: A conventional telescope converted for high resolution earth-watch.

411 Radar Sounder: Used for atmospheric probing of temperature and moisture profiles and precipitation distribution and intensity.

412 Microwave Radiometer: Used to obtain good resolution ground contours in all weather with passive microwave.

414 Microwave Altimeter: An altimeter used to measure ocean height, wave height, flood levels, snow cover.

415 Microwave Spec meter: Multiple-band transceiver with high resolution scanning filter to measur coherent surface reflections for sea-surface temperature, atmospheric water vapor and ice cover.

TABLE 3.1.4-2. SCIENCE AND APPLICATIONS INSTRUMENTS

EARTH OBSERVATIONS
AGRICULTURE, METEOROLOGY, HYDROLOGY, GEOPHYSICS

CODE	NAME	COST $M	AVERAGE POWER 1 kW	LAUNCH WEIGHT kgm	LAUNCH VOLUME m^3	DATA PROCESS 2	TELEMETRY RATE 3	LEO INCLIN 4	POINTING DIRECT 5
401	Imaging Spectrometer	50	2	500	3	H	L	HL,PL	E+
402	Laser Ranger	25	1	200	2	L	L	HL,PL	E
403	Multispectral Scanner	25	1	150	2	H	H	HL,PL	E
404	SAR	50	100	1000	15	H	H	HL,PL	E+
405	Optical Lidar	15	5	100	2	L	L	A	E
406	Camera Hi-Res	5	0	200	2	L	L	HL,PL	E
407	Scatterometer	20	5	500	15	M	M	HL,PL	E
408	Interferometer	10	1	75	2	L	L	A	E
409	Video Camera	1	.5	50	1	L	L	A	E
410	Optical Telescope	10	1	300	3	L	L	HL,PL	E+
411	Radar Sounder Altimeter	40	5	500	15	M	L	HL,PL	E
412	Microwave Radiometer	30	1	300	15	M	M	HL,PL	E
414	Microwave Altimeter	40	5	500	15	L	L	HL,PL	E
415	Microwave Spectrometer	30	1	300	15	L	L	HL,PL	E

(1) Assumes non-space qualified

(2) Assumes on-board processing

See Table 3.1.2-3 for entry codes

TABLE 3.1.4-2. SCIENCE AND APPLICATIONS INSTRUMENTS

EARTH OBSERVATIONS
AGRICULTURE, METEOROLOGY, HYDROLOGY, GEOPHYSICS

CODE	NAME	POINTING STABIL 6	VEHICLE SITE 7	ENVIRON SUSCEPT 8	ENVIRON PERTURB 9	SETUP TIME hrs	INSTRUMENT OPERATION hrs/dy	INSTRUMENT OPERATION dys/yr	CREW INVOLVE mndys/yr
401	Imaging Spectrometer	G	SS	LT	G	2	2	200	50
402	Laser Ranger	G	SS	N	L	2	.1	100	5
403	Multispectral Scanner	G	SS, FF	LT	G	2	3	200	15
404	SAR	G	SS,FF	N	N	4	1	100	15
405	Optical Lidar	M	SS,FF	LT	G	2	.1	100	5
406	Camera Hi-Res	G	SS	LT	N	2	1	100	20
407	Scatterometer	G	SS,FF	N	N	4	2	200	10
408	Interferometer	M	SS,FF	LT	N	$	.1	100	5
409	Video Camera	G	SS	LT	N	1	2	100	25
410	Optical Telescope	G	SS	LT	N	.2	1	150	25
411	Radar Sounder Altimeter	G	SS,FF	NO	N	4	1	150	10
412	Microwave Radiometer	G	SS,FF	N	N	4	1	150	10
414	Microwave Altimeter	G	SS,FF	NO	N	4	1	100	10
415	Microwave Spectrometer	G	SS,FF	NO	N	4	1	100	10

(1) Assumes non-space qualified

(2) Assumes on-board processing

See Table 3.1.2-3 for entry codes

3.1.4.3 Proposed Payloads

The earth observation pallet will serve the needs of a multiplicity of users with a wide diversity of interests. It should be a flexible configuration, versatile in its range of capability, and general purpose in its accommodation of most earth observing requirements. The first facility configuration, as proposed in Table 3.1.4-3, will consist of several instruments. The imaging, pointable spectrometer is expected to become the most used instrument, and it should be modular in design to allow the operator to reconfigure it, for example, in instantaneous field of view, polarization, spectral bandwidth, and number of spectral bands. It should be pointable by the operator or by a programmable computer controlled scan. The altimeter will use mode-locked laser technology to achieve a vertical resolution of less than 6 mm. Its primary uses are contemplated to be in measurement of tectonic movement and sea state although other disciplines will also exploit its capability. The multispectral scanner will be the routine earth observer using well-established and reliable technology to provide data already familiar to many users and incorporated into operating remote sensing systems. A fourth instrument, a tunable lidar, has been suggested for atmospheric and meteorologic investigations, including weather analysis and prediction, and understanding, atmospheric chemistry, movements caused by winds in the several atmospheric layers up to the stratosphere, and the source and sinks of atmospheric particles and gases. The film camera bank, video camera, interferometer, and earth-looking telescope are also proposed for the initial platform.

In addition, there are other earth environment payloads that might fly on later missions. The synthetic aperture radar and a heterodyning CO_2 lidar are two examples that were chosen from the list of possibilities. These three illustrative payloads are used in the case missions of Section 4.0 where the Manifesting Code and overall Mission Requirements are analyzed. Payload characteristics are summarized in Table 3.1.2-5.

3.1.4.4 Facility Requirements

The optical sensors require a clean environment so that windows and lenses are not degraded by condensates. The specialist-operator will actively man the instruments to locate the intended field of view, to minimize unnecessary data collection, and to modify the sensor package as necessary. Because of the potentially high data rate from those instruments, it is proposed that most of the data be processed and analyzed on-board the station with decision-oriented information telemetered to the ground. This will require a capable on-board computer system in an image processing laboratory.

TABLE 3.1.4-3. PROPOSED EARTH OBSERVATIONS PAYLOADS

Payload Code	Payload Name	Experiments Code	Experiments Name
S001	Earth Observation Pallet	401	Imaging Spectrometer
		402	Laser Ranger
		403	Multispectral Scanner
		406	Cameras
		407	Scatterometer
		411	Radar Sounder
		412	Microwave Radiometer
S002	Synthetic Aperture Radar	404	SAR
S003	Heterodyning CO_2 Lidar		

3.1.5 Life Sciences

The Life Sciences are an integral part of the space program. Commercially practical research could result in new or improved substances (i.e., drugs) synthesizable in zero g. The science value of microgravity, in study of Basic Life processes, may help in medical and horticultural applications. The continued role of man in the space environment requires that we come to fully understand the physiological and functional effects of prolonged exposure to microgravity. A more complete description of life sciences research is presented in Section 3.1.5 of Volume 7-1.

3.1.5.1 Life Science Objectives

The primary objectives of Space Station Life Science Research will change with time (Figure 3.1.5-1). During the first five years, medical and medically related experiments will predominate within a dedicated Health Care Module. Initial human studies will center on long-term affects of microgravity and radiation. Additional long term human experiments design will be based on animal research results. About the sixth year the emphasis will shift toward academic and commercial experimentation. Studies will focus on basic life processes, biochemistry and organism development. Microbial and cell culture work may lead to new medicines of commercial value. Animal and plant development experiments will provide clues to role of gravity at the cellular level. Plant growth experiments will provide key data to development of a biologically based controlled ecological life support system (CELSS). Large scale artificial gravity experiments are anticipated to begin about year ten. At year fifteen CELSS dedicated studies will be initiated. These experiments will evaluate the interactions of man, machine, plants, animals and microbials.

3.1.5.2 Potential Instrumentation

Life Science experiments in a Space Station will require the same basic equipment as a well-stocked earth laboratory. Most equipment will require modification to operate in microgravity. Unique equipment, such as a 1-g centrifuge and limb plethysmograph, will be developed on a as needed basis. When possible, each item should be selected to minimize weight, power demand, and volume. Concurrently, maxium automation and reliability are desirable.

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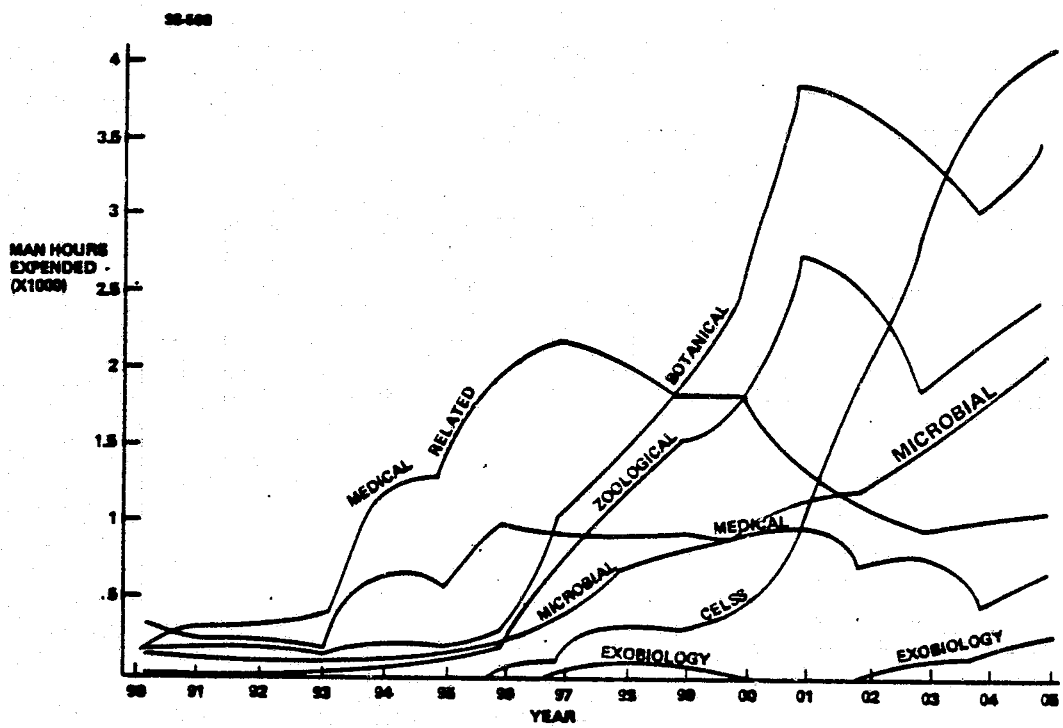

Figure 3.1.5-1. Manhours Expended on Life Sciences Discipline Onboard Space Station

(1) Limitation of life sciences budget through year 2000 were considered based on available information. Year 2001 through 2005 budgets were projected from the previous five year budget growth rate.

A list of 80 potential instruments for life science research on the Space Station is presented in Table 3.1.5-1. General characteristics of these instruments are tabulated as in previous subsections. See Table 3.1.2-2 for the tabular entry code.

3.1.5.3 Proposed Payloads

From this list of instruments and the user data in Volume 7-1, illustrative payloads have been configured to meet the life sciences research objectives. The makeup of each payload is listed in Table 3.1.5-2. Table 3.1.5-3 summarizes the characteristics of the experiments included in the payload analysis. Their instrumentation requirements were collectively used to assemble input data for the Manifesting Code, which determines the overall requirements of each payload. Section 4.0 discusses the aggregate Mission Requirements imposed on the Space Station by all of these proposed payloads.

3.1.5.4 Payload Requirements

We recognize that the life science facilities must conform to the Space Station capabilities and available manpower (Figure 3.1.5-2). As the station matures it could support more complex research facilities. A summary of each facilities utilization is provided in Figure 3.1.5-3. The projection of facility use is based on Space Station capability, STS delivery manifesting, manhours available, life science objectives and facility design. The initial designs are for small, low power units. These "suitcase" experiments will require little man tending. When the STS manifest allows, a space available package can be carried to the Space Station. These units will have low power and ECLSS requirements. They may be internally or externally mounted. Each unit will contain experiments or equipment that requires some low level of man tending. These two types of facilities will suffice for early medical and biological research. The life science research facility (LSRF) design will adapt to the Space Station with minimal impact on ECLSS. The LSRF will require Space Station power, unless an independent power supply is added to the design. The LSRF would incorporate existing space available equipment. The combination of LSRF and a 1g centrifuge would form a complete life sciences laboratory including plant, animal and microbial holding facilities. A CELSS module would be delivered after the lessons learned from Space Station research had generated an adequate data base to commence equipment-organism integration studies. Ultimately the CELSS module would provide partial ECLSS support to the Space Stations. Medical research will utilize the equipment provided for operational medicine. This facility will grow in capability until it reaches an emergency

surgery capacity. Specialized and some early experiments will be conducted with space available units.

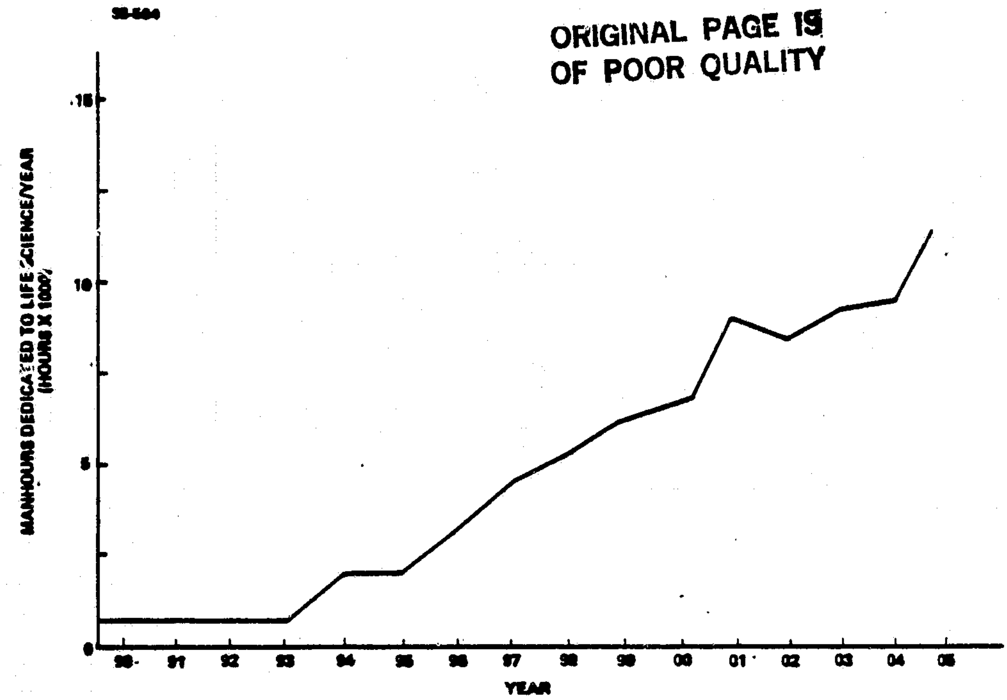

Figure 3.1.5-2. Manhours Expended Onboard Space Station for Life Sciences

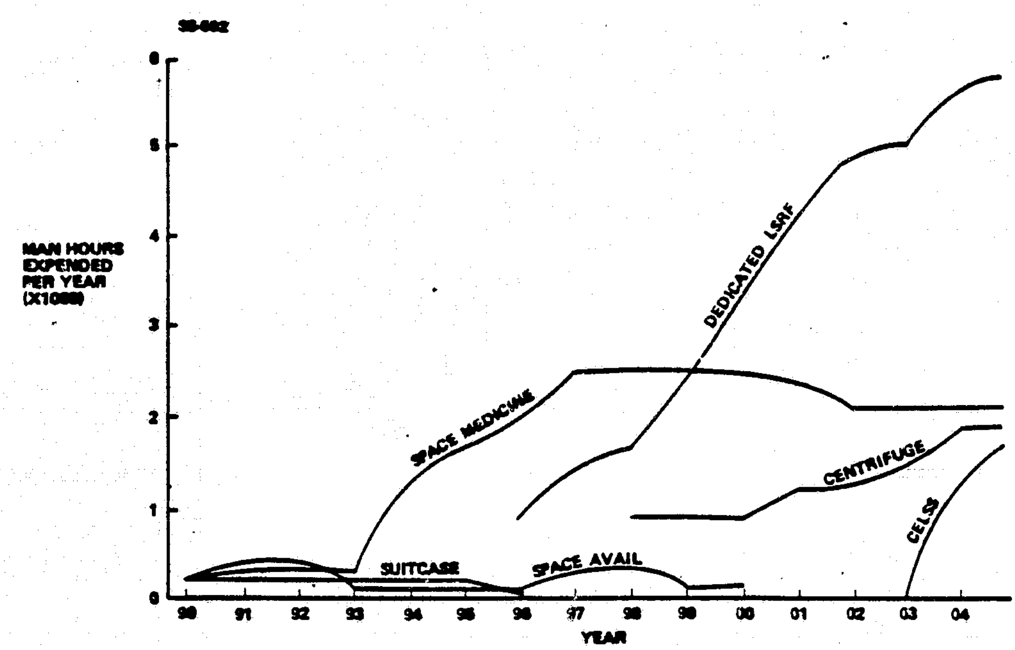

Figure 3.1.5-3. Manned Space Station Onboard Life Science Research Effort Growth

Table 3.1.5-1. Space Sciences and Applications Life Sciences

CODE	NAME	AVERAGE POWER 1 KW	LAUNCH WEIGHT KGM	LAUNCH VOLUME M^3	DATA PROCESS 2	TELEMETRY RATE 3	SETUP TIME HOURS	INSTRUMENT OPERATION HOURS/DAY	INSTRUMENT OPERATION DAYS/YEAR	CREW INVOLVE MANDAYS/YEAR
601	AIR PART SAMP	0	3	.001	L	M	0	12	52	49
602	PART ANAL						.5			
603	ARTER PRESS REC				L	L	.3	.5		
604	AUDIOMETER									
605	AUTORADIOGRAPH									
606	BEHAV EVAL KIT									
607	BLOOD CHEM ANAL	0	8	$5x10^{-2}$	L	NA	.5	1	104	104
608	BLOOD GAS ANALY	40	2	$1x1x10^{-2}$	L	NA	.2	1	104	104
609	LABWARE	0	50	$8.5x10^{-2}$	NA	NA	NA	NA		
610	STILL CAMERA	0	1.97	$1.0x10^{-3}$	NA	NA	.2	.2	365	365
611	CARDIOGRAPH	175	.3	M	M	LL	.7	2	104	208
612	H/S CENTRIFUGE	.48	90	$5.1x10^{-1}$	NA	NA	.6	5	156	156
613	MICRO CENTRIFUGE	.100	5	$6x10^{-3}$	NA	NA	.4	.8	104	83.2
614	1G CENTRIFUGE	4	6350	250	M	L	1 - 24	24	365	438
615	CHEM ANAL SET	10	18	$1.0x10^{-1}$	NA	NA	1.5	3.5	156	382
616	CRYOGENIC SYS	0	45	$4.3x10^{-2}$	NA	NA	2	1	104	41.6
617	DATA MANAGEMENT UNIT	1.2	124	$1.6x10^{-1}$	H	H	4 - 48	24	365	1752
618	DECOMPRESSION CHAMBER						1			
619	DEHYDRATED MEDIA									
620	DENTAL INSTRUMENTS									
621	DESSICATOR (VAC)	0	5	$5.7x10^{-2}$	NA	NA	.5	8	104	41.6
622	DIAGNOSTIC IMAGE SYS									
623	X-RAY									
624	DISSECTION KIT									
625	DOPPLER FLOWMETER									
626	DOSIMETER	0		6	L	L	.1	24	365	87.6
627	DYANOMOMETER									
628	ECG/EVG	.800	90.7	$2.1x10^{-2}$	M	M				
629	EEG	.02	9	$2.8x10^{3}$	M	L	.8	1.4	52	109.2
630	EMG	BATTERY	5.5x10	$2.2x10^{-5}$	L	L	4 - 8	24	260	312
631	EOG	1	.5	.0001	L	L	.7	2.3	52	179.4
632	FILTER APPARATUS	0	2	$1.4x10^{-2}$	NA	NA	.6	1.3	26	50.7
633	FREEZER LN_2	0	12.5	$2.32x10^{-2}$	NA	NA	1.2	2.8	104	58.2
634	GAS CHROMATGRAPH	100	5	$1.7x10^{-2}$	NA	NA	.1	24	365	175.2
635	HISTOLOGY KIT	0	2	$2.8x10^{-2}$	NA	NA	.4	4	312	99.8
636	HOLDING FACILITY	.265 - .585	256	$3.6x10^{-1}$	M	L	.3	NA	NA	
637	INCUBATOR	.08	45	.129	M	L	1.5	24	365	525.6
638	INJECTION EQUIPMENT				NA	NA	2.5	24	365	350.4
639	IV FLUID SYSTEM				NA	NA				
640	LAMINAR WORK TABLE	.5	180	$8.5x10^{-1}$	.8					

SEE TABLE 3.1.2-3 FOR ENTRY CODE.

NOTE: LEO INCLINATION 4 = LL FOR ALL EXCEPT CODE 611, 615, 627
VEHICLE SITE 7 = SS FOR ALL CODES
ENVIRONMENTAL SUSCEPTABILITY 8 = BM, TM FOR ALL CODES

Table 3.1.5-1. *Space Sciences and Applications Life Sciences (Continued)*

CODE	NAME	AVERAGE POWER 1 KW	LAUNCH WEIGHT KGM	LAUNCH VOLUME M^3	DATA PROCESS 2	TELEMETRY RATE 3	SETUP TIME HOURS	INSTRUMENT OPERATION HOURS/ DAY	INSTRUMENT OPERATION DAYS/ YEAR	CREW INVOLVE MANDAYS/ YEAR
641	LIM PLETHYSMOGRAPH	BATTERY	1	3.69×10^{-4}	L	NA	.9	3	260	280 7
642	LWR BODY NEG PRES. UNIT	5	78	.64	L	NA	.1	.3	104	46.8
643	LYDPHILIZE	0	5	2.3×10^{-2}	NA	NA	.5	2	28	36
644	MACROMASS MEASURE	1.5×10^{-2}	34	.68	L	NA	.2	.6	26	4.68
645	MICROMASS MEASURE	.015	15	3.86×10^{-2}	L	NA	.3	.8	312	174.7
646	METABOLIC ANAL	.03	18	.1	M	L	.2	.7	312	.7
647	MICROBIOLOGY KIT	0	2	2.8×10^{-2}	NA	NA	.3	6	312	93.6
648	MICROTOME	0	5	9×10^{-3}	NA	NA	.5	2	208	291
649	MICRO MANIPULATOR	0	2.3	.18	NA	NA	2.2	4.5	52	187.2
650	MICROSCOPE STEREO	.03	13.6	2.8×10^{-2}	NA	NA	.6	2.3	52	119.6
651	UV/LIGHT/IR	.110	18	5.1×10^{-2}	M	M	.1	2	312	.8
652	ELECTRON				H	H	.4	2	312	.5
653	OHMMETER	BATTERY	.621	8.8×10^{-3}	NA	NA	2.6	4	104	.9
654	OSCILLOSCOPE	BATTERY	1.6	2.4×10^{-3}	M	M	.1	.5	156	.2
655	OVEN	1	2	2.8×10^{-2}	NA	NA	.2	.9	208	.6
656	PH METER	12	5	1.4×10^{-2}	L	NA	.2	4	75	.05
657	PHYSIOLOGIC GAS ANAL	10	2	7×10^{-3}	M	L	.1	1.5	104	1.4
658	PLANT TOOLS	0	15	.18	NA	NA	.4	1	104	.3
659	PLATE SCAN CTR	.02	9	2.8×10^{-2}	M	L	.1	2	52	1
660	POLARGRAPHIC O_2/CO_2	0	2	2.8×10^{-2}	L	NA	.3	.5	260	.5
661	PRESERVATION MATERIAL				NA	NA	.2	24	365	.01
662	PULMONARY FUNCTION MEASURE KIT	.2	175	.3	L	L	.1	NA		
663	PSYCHOMETERICS UNIT				NA	NA	.1	.4	52	1
664	RADIOBIOLOGY UNIT	0	12	6.5×10^{-3}	M	M	.2	1	52	1
665	REFRIGERATOR	.350	34.9	1.8×10^{-1}	NA	NA	1.5	2	104	.4
666	ROTATING LITTER CHAIR	.450	23	.1	NA	NA	.1	24	365	.05
669	STAIN KITS	50	9	5.7×10^{-2}	NA	NA	.3	.7	52	1
670	STERILIZERS	1	11	6×10^{-1}	NA	NA	.2	NA		
671	SIGNAL GENERATOR	50	2	1.4×10^{-2}	M	NA	.3	NA		43.6
672	SURGICAL INSTRUMENT KIT				NA	NA	.6	4	182	.1
673	TEMPERATURE BLOCK	25	2	8×10^{-2}	L	NA	.1	.5	104	.4
674	CLOCK/TIMER	0.1	$.9 \times 10^{-2}$	.01	M	M		NA		
675	TISSUE CULTURE CHAMBER	16	10.1	1.2×10^{-2}	M	M	.2	24	365	.01
676	TRACE GAS MONITOR	500	45	5.1×10^{-1}	L	NA	.1	24	365	.001
677	TV/VIDEO CINEMA	240	48.5	4.5×10^{-2}	H	H	2.7	24	365	.05
678	URINE ANALYZER	50 - 85	18	2.2×10^{-2}	L	NA	.6	8	365	.05
679	VET MED KIT	0	2	2.8×10^{-2}	NA	NA	.4	1	104	.7
680	VOLTMETER				NA	NA	.1	NA		
681	WASHER, CAGE	500	90	2.8×10^{-1}	NA	NA	1.5	2	13	.3
682	WASHER, TOOLS	.5	4.5	1.4×10^{-1}	NA	NA	.8	2	182	.2

SEE TABLE 3.1.2-3 FOR ENTRY CODE

NOTE: LEO INCLINATION 4 = LL FOR ALL EXCEPT CODE 611, 615, 627
VEHICLE SITE 7 = SS FOR ALL CODES
ENVIRONMENTAL SUSCEPTABILITY 8 = BM, TM FOR ALL CODES

TABLE 3.1.5-2. PROPOSED LIFE SCIENCES PAYLOADS(1)

PAYLOAD Code	PAYLOAD Name	EXPERIMENTS Code	EXPERIMENTS Name
SL01	Human Life Sciences Carry Ons	501	Cardio-Pulmonary
		503	Sensory Systems
		504	Musculo-Skeletal
SL02	Small Mammals Carry Ons	505	Bone Loss
		506	Muscle Loss
		507	Fluid and Electrolyte Balance
		508	Cardiovascular
		509	Metabolism
		510	Vestibular Physiology
SL03	Plant Development Carry Ons	515	Physiology
		516	Development
SL04	Small Mammal Research Facility	511	Vestibular Function
		514	Reproduction
SL05	Centrifuge (for SL04)	513	Animal Development
SL06	Closed Environment Module	517	Closed Environment Life Support System
SL08	Small Mammal Radiation Biology	512	Radiation Biology

(1) Experiments identified with each payload are only those that would be carried into orbit with that payload. Facilities in orbit will have additional experiments added throughout their life.

TABLE 3.1.5-3. SCIENCE AND APPLICATIONS–LIFE SCIENCES CONFIGURATION CHARACTERISTICS

SCIENCE AND APPLICATIONS MISSIONS / LIFE SCIENCES MISSION INTERFACE CHARACTERISTICS	ORBIT		PROGRAM				SIZE/ WEIGHT		INTERFACE										OPERATIONS			ENVIRONMENT			
	INCLINATION (DEGREES)	ALTITUDE (KM) – (A) ANY, (L) LOW	SCHEDULE (YEAR) (1)	NUMBER OF FLIGHTS	DURATION (MONTHS) (2)	UPPER STAGE	VOLUME (M^3)	WEIGHT (KG)	POWER AV./PEAK (KW)	HEAT REJECTION MIN/MAX	ORIENTATION - (I) (S) (E) (A) ANY	POINTING/STAB ARC SEC/ARC-SEC/SEC	DATA	BERTHING PORT	INTERNAL	EXTERNAL	S.S. MANIPULATOR	PLATFORM (P) HANGAR (H)	IVA	EVA	FREE FLYER SERVICING (S), REMOTE (R)	LOW CONTAMINATION	"0" G	MICRO METEROID PROTECTION	RADIATION PROTECTION
HUMAN CARDIOPULMONARY SYSTEM	28.5	L	90/04	1	12		1.4	97	0.9	0.9	A		M		X				X	X					
HUMAN BODY FLUIDS	28.5	L	90/04	1	12		0.1	6	0		A		L		X				X						
HUMAN SENSORY SYSTEM	28.5	L	90/99	1	6		0.1	177	0.4	0.4	A		L		X				X	X					
NON-HUMAN CARDIOVASCULAR	28.5	L	90/93	4	12		0.4	256	0.7	0.7	A		L		X				X						
VESTIBULAR PHYSIOLOGY IN SMALL MAMMALS	28.5	L	90/91	7	12		0.4	265	0.6	0.6	A		L		X				X						
HUMAN MUSCULOSKELETAL	28.5	L	90/[illegible]	1	12		1.9	134	0.4	0.4	A		L		X				X						
BONE LOSS IN SMALL MAMMALS	28.5	L	90/93	6	12		0.4	256	0.6	0.6	A		L		X				X						
MUSCLE LOSS IN SMALL MAMMALS	28.5	L	91/93	6	12		0.4	256	0.6	0.6	A		L		X				X						
NON-HUMAN MAMMALIAN METABOLISM	28.5	L	91/93	5	12		1.4	291	0.9	0.9	A		M		X				X						
PLANT PHYSIOLOGY	28.5	L	91/95	23	12		0.5	70	0.3	0.3	A		L		X				X						
FLUID ELECTROLYTE IN SMALL MAMMALS	28.5	L	92/95	4	12		0.4	256	0.6	0.6	A		L		X				X						
PLANT DEVELOPMENT	28.5	L	92/96	24	12		0.5	70	0.3	0.3	A		L		X				X						
VESTIBULAR FUNCTIONS IN SMALL MAMMALS	28.5	L	94/95	3	12		0.4	262	0.7	0.7	A		L		X				X						
REPRODUCTION IN SMALL MAMMALS	28.5	L	95/99	13	1		64	5339	11.5	11.5	A		L	X	X				X						
ANIMAL DEVELOPMENT	28.5	L	97/04	7	12		43.9	430	4.2	4.2	A		L	X	X				X						
CLOSED ENVIRONMENT LIFE SUPPORT SYSTEM	28.5	L	97/00	6	12		64	3273	9.7	9.7	A		H	X					X						
RADIATION BIO IN SMALL MAMMALS	90	A	97/99	3	12		0.4	268	0.6	0.6	A		L		X				X						X

(1) Valves with slash indicate year of first experiment began and year that last experiment ends.

(2) Value indicates number of months per year one or more of indicated

3.1.5.5 Crew Requirements

The Life Sciences personnel will serve dual functions as (a) the medical personnel for the station and (b) the Life Science researchers.

The medical tasks and some of the life sciences research tasks will be highly interrelated and closely interconnected. Other life sciences tasks will be only slightly related to the medical tasks. During the initial years of the space station, only the life sciences research that pertains to the effects of zero-g on humans will be similar to practicing medicine. Most of the other early life sciences research will involve small suitcase experiments.

The early space station life sciences/medical personnel will need the following skills:

- Medical training to the level of a paramedic
- Basic electronic technician skills
- Basic diagnostic and troubleshooting skills
- Basic training in non-human life sciences

As the space station facility and staff grows, the life sciences tasks will expand and evolve. Eventually true interactive life science research, on topics other than the effects of radiation and zero-g, will be conducted on the space station. At this point in time, the life sciences personnel will need to have advanced training on the research in progress.

3.1.5.6 Dornier Study

Dornier System GmbH conducted a parallel study of life sciences on a space station. They provided a description of European life sciences research activities in the 1980's and their projections of life sciences, human physiology, and medicine research activities in the 1980's.

Mission scenarios for the various subdisciplines of life sciences and life support development for Space Station applications were defined to a level of detail which will enable the analysis of various architectural options for a Space Station.

The life sciences community has well-defined objectives for their activities in the 1990's and the potential use of the Space Station. These objectives provided the basis for the analysis

of mission criteria, the experiment time phasing and the determination of typical Space Station requirements for the various life sciences subdisciplines.

The life sciences program was split into:

- Life Sciences Research (basic; Gravitational Biology, Radiation Biology and Exobiology)
- Human Physiology and Medicine, and
- Life Support Systems.

This enabled a clear requirements definition and a logical buildup of the activities on a Space Station. Furthermore the distinct character of a Space Station subsystem for the Operational Medicine and the Life Support Systems is pronounced by the foreseeable dedicated Medical Clinic and Health Care Module.

The life sciences community provided detailed equipment lists for each of the subdisciplines. These lists supported the elaboration of Space Station requirements for a set of typical payloads.

The strong interest of the European Life Sciences Community in the use of a Space Station was documented by their participation in a German workshop for potential users of a Space Station held during the course of this study. This workshop provided valuable data on the use of a Space Station for life sciences research and life support system development.

The complete Dornier final report is found in Volume 7-1.

3.1.6 Materials Sciences

This section summarizes our analysis of materials processing in space research at a space station. Our subcontractor, Authur D. Little, prepared this information. Their full final report is found in the Vol. 7-2 Data Book.

Materials Processing in Space (MPS) is at the early phase of an evolutionary development. At the time of a Manned Space Station MPS will be at verification of concept (VOC) and engineering demonstration (ED) phases. These phases will have had extensive ground-based research and (in many cases) shuttle/Spacelab investigation of concept (IOC) phases as precursors. In the period before the deployment of the space station there must have been at least 5 years of continuous commitment to IOC at a level of at least $30 million per year. Such a commitment would be adequate to support about 50 ground-based (IOC) research endeavors during one year. In the early years, from these 50 experiments, about 10 may be selected for flight and accommodation on the space station. In addition, a modification to these 10 experiments, or 10 new experiments, would take place each year. Therefore, approximately 20 planned experiments could be conducted each year. Should the MPS facility aboard the space station be made available to international participants, there would probably be a doubling of experimental activity.

The most important advantages of the space station over the shuttle/Spacelab are that it would provide experimentation facilities with much more power and greatly extended time in space. The space station would also allow the presence of the human experimenter in space. Human experimenters are essential in the early phases of MPS development because it is only after a process has been reduced to a routine that automated manufacture can be considered.

The space station as a facility for MPS can be a national (or international) laboratory for continued research and development in materials that exploit the unique low-gravity environment of space. The early configuration and capabilities will be determined by the prior commitment to MPS and the experience gained through use of the shuttle/Spacelab. Because this commitment may justify only about 10 VOC and/or ED endeavors per year, the start-up of MPS activities aboard the space station should be designed accordingly. Success, even at this modest activity level however, will stimulate construction of new facilities as needed. The industrial infrastructure and technological capabilities that produced the space station should be adequate to meet the requirements for future expansion of MPS activities.

3.1.6.1 Technical Requirements

Basis—The following is a list of candidate, multi-purpose MPS experiment systems which may require accommodation in a space station:

- o Solidification Experiment Processing System
- o High Gradient Furnace Processing System
- o Elecromagnetic Containerless Processing System
- o Isoelectric Focusing Separation System
- o Float Zone Processing System
- o Acoustic Containerless Processing System
- o Electrostatic Containerless Processing System
- o Solution Crystal Growth Processing System
- o Vapor Crystal Growth Processing System
- o Bioprocessing Systems
- o Fluid Science Facility
- o Combustion Science Facility
- o Extraterrestrial Materials Processing Demonstrations

It is anticipated that these experiments would be conducted in an "open" laboratory environment. At the same time, however certain commercial MPS efforts might have to be accommodated by the space platform. One example of such a commercial system would be Electrophoresis Operations. To insure the protection of proprietary research and production, the space station may have to be constructed to allow the attachment of laboratory modules that simultaneously could access the station's utilities and could guarantee privacy. These modules could either be rented or owned by the commercial sponsor. If owned, the space station's utilities could be rented or user charges levied.

Volume and Mass—The requirements for MPS laboratory facilities will be determined by the number of experiments, the scope of the federal and industry-funded MPS program, and decisions regarding international use of space station facilities. Assuming the continuation of a MPS program beyond shuttle/Spacelab, 10 double (Spacelab) racks integrated into a Spacelab-like enclosure with climate control for payload specialists who work in a "shirtsleeve" environment could be required. The equipment could be housed in an expanded version of the cylindrical Spacelab module. Such a module, complete with climate control,

waste heat, and electric services, but empty of experiments, would have a diameter of 4m and length of 10m, a volume of $126m^3$, and a mass of 12000 kg. Each double rack would have a mass capability of approximately 500 kg. Other mission-dependent materials could have a mass of 2000 kg. Therefore, the estimated total volume and mass for an initial version of a MPS facility on the space station is about $130m^3$ and 19,000 kg respectively. International participation agreements could double these numbers. (In the subsequent discussions laboratory facilities designed for both international and U.S. use should be multiplied by a factor of two). The arrangement of the axes of the basically cylindrical configuration of the facility would be determined by the appropriate match to the overall configuration of the space station.

Power—The limits to the availability of power (about 1.5 kW continuous) on the shuttle/ Spacelab is currently one of the most constraining influences on MPS. Experiments with high melting point materials (most notably the electronic materials with a high commercial value) will dominate the power requirements of the MPS facility. A float-zone processing experiment is an example of an experiment requiring a large amount of power when designed to allow free, 360° access to instrument observation of a molten zone. In this case, about 16 kW are required for the heat source to process a 5 cm diameter sample of silicon (1410 C melting point temperature) using an incandescent source with focusing reflective optics. The power required to process samples having different sizes and melting points is proportional to the square of the sample diameter and approximately proportional to its absolute melting point temperature.

An example of an intermediate power requirement for the processing of electronic materials would involve the use of an insulated high gradient (250 K/cm) furnace. In this case, the insulating enclosure of the furnace reduces the required power considerably. To process a 5 cm diameter sample of an electronic material with a melting point of 1400 C in such a furnace would require a power source of approximately 1 kW. This power requirement is nearly proportional to the square of the sample diameter and the design temperature gradient of the furnace and only weakly dependent on the melting point temperature of the sample.

All experiments have a minimum power requirement needed for experiment manipulators, data handling and display, controls, and instruments. A reasonable estimate of these requirements, based on Spacelab experiment requirements, is approximately 0.5 kW per

experiment system. Most experiments at room temperature do not appreciably exceed this minimum power requirement. The use of 1.0 kW per room temperature experiment can reasonably be assumed.

Within these technical guidelines one can estimate the power requirements for an early version of a MPS facility for a space station based on the capabilities identified in Table 3.1.6-1.

Table 3.1.6-1 ESTIMATED POWER REQUIREMENTS FOR EARLY VERSIONS OF MPS FACILITY

Experimental Multi-Purpose Experiment Facilities	Processing Temperature (C)	Sample Diameter (cm)	Power Heating Source (kW)	Other
one (1) high-power electronic materials processing	1500	5	16	0.5
four (4) intermediate power electronics materials processing	1500	5	4	2.0
five (5) room temperature (pharmaceutical and other)	25	–	–	5.0
Subtotal: 10 multipurpose experiment systems			20	7.5
Approximate Total 30				

The power required for the early versions of an MPS facility will be dominated by the processing needs of electronic materials. These needs are dependent on and adjustable to, the size of the sample to be processed and, to a lesser degree, on the processing temperature.

Larger size samples for experiments may be required to demonstrate the validity of the process on a pilot plant scale. This increase in scale will require one or two orders of magnitude greater power as success of experimentation beyond the ED phase dictates.

<u>Thermal Control</u> - The thermal power to be rejected from the MPS facility is the sum of its power inputs for experiment operation and climate control. The power required for experiment operations will dominate and be nearly equal to the power input required. For the early versions of the MPS facility this power is estimated to be 30kW. The heat rejection temperature for most of this power is near room temperature. A thermal utility to accept this heat and reject it to a space radiator will be required. Recent concepts for this utility which make use of working fluids in pumped, two-phase flow have advantages in near-isothermal operation, flexible piping arrangements, and small pumping power compared with the pumped, liquid fluid systems currently used with the shuttle/Spacelab systems. The mass and power requirements for such a thermal utility system, exclusive of the space radiator, for 30 kW heat rejection are relatively small: approximately 400 g and 20 W. These figures are included in the estimates of the weight previously given.

<u>Microgravity, Vacuum, and Radiation</u> - The major scientific and technical argument for MPS is to exploit the low-gravity environment obtainable in space. A zero-gravity environment is the ideal for scientific investigation, but this ideal can only be approached on a manned space station which has multi-purpose missions. It is expected that a dedicated shuttle/Spacelab can maintain a 10^{-5}g background level with acceleration spikes up to 10^{-2}g due to crew activity. These levels are presently accepted as tolerable for a wide range of useful MPS experiments, although lowering of these accelerations is desired. As the dedication of a manned space station to MPS activity may be in question, the means to achieve low-gravity levels in the MPS laboratory needs further attention. Systems for isolating the laboratory from the main frame or the experiment systems from the laboratory may be required.

Although an extensive region of ultra-high vacuum can be made available in the wake region of a specially-designed shield, there has been no impetus to use the vacuum availability of space as a prime factor in MPS. The reason is that a vacuum level down to the 10^{-13} torr can be obtained in laboratory research chambers on Earth. Also, chamber volumes measured in 10^4 cubic meters can be maintained at 10^{-6} torr by practically available means. Accordingly, early use of the vacuum of space is likely to be confined to its application as a pump to provide the vacuum environment useful to some equipment systems. Such is the case for the current Spacelab module in which the only access that the experiment systems have to the space vacuum is through a single tube about 3.5cm in diameter and 4m long. This access is only suitable as a fore pump for high-vacuum pumps to be included in the

experiments which require it. It may seem ironic that, with the apparent availability of the space vacuum, high-vacuum pumps would be needed to service certain experiments on Spacelab. This apparent contradiction resulted from past tradeoff studies. The use of the space vacuum as a fore pump only may require that future design tradeoffs be applied to the space station.

Automation, Data Handling - As described in the next section, a human operator is essential to MPS research and development through the engineering stage. At the same time the maintenance of humans is expensive in terms of materials life support and power supply requirements. These requirements may become the determinants of the time limits set for experimentation. Accordingly the payload specialists should be used to perform only those tasks that humans are best able to perform: experiment set-up and disassembly, delicate manipulation, critical overall observation, assessment and "troubleshooting" of observed experiment abnormalities, and repair and maintenance, where practical. The execution of experiment protocol, with the exceptions noted, should be automated as much as practical. Each experiment would have its own best balance between human and machine operations. This balance would have the experimental operations controlled by microprocessors and the measurement and data logging completely automated. The sequencing of one experiment from one control mode to another could involve human judgment and intervention. For example, the payload specialists may be called upon to review the comparison between the experimental data and the expected results before switching over to the next test sequence.

Details of the data handling system will be specific to each experiment; however, one can anticipate their common architecture. The number of variables measured in each experiment would be conditioned to electric form, adjusted to a standard level, and converted, as necessary, to digital form. The digital representation would be sent to a microcomputer for storage and further processing control as required. Status signals of the yes/no variety, such as switch closures or logic level signals, also enter the computer through the digital interface. Data display on a CRT would be controlled by the payload specialist using a keyboard entry. A video and cine camera might be used for a realtime and a permanent vital reference for critical experiment observations. In addition, selected experiment data will be telometered down-link to the payload operations control center for analysis.

Operations and Maintenance - Except for the housekeeping activities, the operation of the MPS laboratory will be mission-specific within the constraints of service power, heat rejection, data handling, and crew resources. These resources will be time-lined to best accommodate the requirements and goals of the experimental activities.

The maintenance of the laboratory facility and its experiment systems will be of the "remove-and-replace" type. A high level of quality assurance and reliability must be built into these systems not only to assure crew safety but because of the high value of the results of MPS experiments. The costs and risks involved with the reliability of the experiment systems are amplified in Section 3.1.6.2.

Summary - A summary of the major technical requirements for a national MPS laboratory facility on the manned space station is given in Table 3.1.6-2.

3.1.6.2 Personnel Requirement

Role of Man - The human involvement in process and product development is absolutely essential in R&D phases. Ability to reason and interpret and manipulative abilities have no successful substitute in automation. It is only after sufficient knowledge has been obtained to reduce a process to repeatability and a production routine that automation becomes an economic alternative. The use of automation deserves particular emphasis in connection with space processing because of the cost of dedicated crew time in space. Nevertheless, these crew costs will not fundamentally change the human role in R&D. In space activities these costs will serve to advance the economic point of transfer to automation in the production cycle.

Safety - As in all similar endeavors, there is a need to establish levels of quality assurance, equipment reliability, and management review procedures for MPS experiments consistent with acceptable risk/management standards. These standards reflect the social or political perceptions of society. The standards developed for the STS are likely to serve in a somewhat modified form for the space station. At this time, although the shuttle/Spacelab is designed as a scientific laboratory in space, the substantial cost of the experimental apparatus and preceeding research have created pressures to obtain "successful" results. Therefore, the procedures which apply to the flight experiments are much like those of an Apollo mission.

Table 3.1.6-2 Estimated Requirements for MPS Laboratory on Space Station (Initial Version)

ITEM	VALUE	COMMENTS
Envelope Dimensions	Cylinder, 4m dia x 10m long	Extended version of Spacelab long modules
Box Volume	130 m^3	
Mission Independent Mass	12,000 kg	
Payload Capability	7,000 kg	
Total Takeoff Mass	19,000 kg	
Electric Power	30 kW	An order of magnitude more power than available on shuttle/Spacelab
Number of Multi-Purpose Experiment Systems	10	Accommodated by 10 double rack installations
Heat Rejection	30 kW	
Crew Complement	4	
Consumables	TBD	Dominated by crew support needs, therefore are approximately proportioned to mission duration
Data Handling	TBD	Experiment specific, highly automated
Operations and Maintenance	TBD	Remove and replace type; procedures will be outgrowth of shuttle/Spacelab experience-proven procedures

The effect of this approach is that the cost of the experimental facilities on shuttle/Spacelab is about fifty times their equivalent in a ground-based laboratory. Standards for design and operating procedures to insure a reasonable level of crew safety must be maintained, but the transient influence of being in the public eye must gradually recede. Although there are no easy solutions to the cost/risk dilemma confronting the individuals and organizations involved in MPS experiments aboard a space station, detailed assessments to reduce the cost impact on these experiments are warranted. It may well be that a lower cost/risk ratio is more appropriate to the early phases of MPS so as not to reduce the opportunities for trial and error so characteristic of preliminary experiments in Earth-based laboratories.

Training - Trained payload specialists are needed to conduct the in-flight experiments. The shuttle/Spacelab experience will serve to identify the professional backgrounds and special training required of these specialists. At this time, it is anticipated that a normally healthy person can conduct space experiments, with no special physical attributes required.

The ideal payload specialist would be one who has been intimately associated with the ground-based research leading to the flight experiment. Failing such a candidate, one with a similar, experience background, interest, and motiviation would serve the purpose.

As a training facility, it is appropriate that the engineering models of the flight hardware systems be set up at a designated NASA center to enable the payload specialists to rehearse the flight experiments in as much detail as possible. While the space processing conditions of near-zero gravity cannot be duplicated in their entirety on Earth, the operational features of the experiment can be rehearsed. Through this rehearsal, possible problems of experimentation will come to light and hands-on familiarity with the experiment systems will be gained by the payload specialists. A two-to-four month period of intensive training should suffice for training of a qualified payload specialist.

The current plan calls for three persons (one mission specialist and two payload specialists) to carry out the experiments on a fully loaded Spacelab involving approximately 10 experiment systems. Because of the greater complexity and duration of the experiments on the space station, a crew of four can be adopted to estimate the personnel needs for the MPS facility on the space station. In its early stages, we have estimated that this facility will have approximately 10 experimental systems if it operates as a national space laboratory. These systems will be programmed to accept two separate experimental

protocols per year. To service these experiments, two crews of 4 persons each, with one 4 person crew as backup, appears to be a reasonable complement for the first activity year. Crew needs will likely expand with the success of the early mission. In addition, making the facility available to international use would double the activity and need for personnel.

3.1.6.3 Transportation

Resupply - STS will provide the transportation needs of MPS on the space station. The resupply for the MPS facility will be totally dominated by the crew consumables in all stages of MPS development up to the pilot demonstration phase. A few kilograms of base materials and a few tens of kilograms of consumables (such as gas bottles) for each experiment would be a normal requirement. Moreover, materials which look sufficiently promising to pass into the pilot demonstration phase must have very high specific value, of the order of $5000-$10,000/kg. The materials base of a 1000 kg product would therefore be valued at $5 to $10 million. From this perspective the requirements for product supply for MPS activity in the foreseeable future will be modest.

Crew consumables can be estimated on the basis of man-days, per mission (reflecting four persons per experiment mission) times the mission duration, which may typically range from 30 to 180 days.

Product Return - The product resulting from MPS for ground evaluations would be off-loaded from the space station and returned to Earth via the STS with each rotation of the payload specialists crew. Many of these products must receive special handling (packing for temperature and contamination control etc.) in accordance with the experiment design requirement specification. The payload specialist will be responsible for overseeing satisfactory adherence to these specifications.

3.2 COMMERCIAL MISSIONS

Commercial missions are those undertaken for profit by private industry. They are distinguished from the other mission classes in that the traffic is driven by the market demand. The government is paid for the use of the Space Transportation System and space station, so the traffic is not tied directly to federal budget constraints. In a mature commercial industry it is assumed that little or no costs are borne by the government for its services and facilities. The scope of commercial missions described here includes communications satellites, materials processing, earth observations, and industrial services.

3.2.1 Commercial Communications Missions

3.2.1.1 Introduction

There is an ongoing trend in commercial communications satellite development toward systems which can provide greater traffic handling capacity, service more users directly, and provide new services that current systems cannot provide. Satellites for these advanced systems of the 1990 - 2005 timeframe would have to be larger, higher-powered, and more complex than current satellites. A manned space station could support the deployment and operations of these systems with final integration and test activities, launch servicing, and repair/maintenance. A space station can also support advanced satellite development by providing a base for new concepts testing.

A variety of missions has been considered for communications satellite utilization of a manned space station. A summary of the generic functions considered in this study is given in Table 3.2.1-1.

Of the various possible uses for the space stations, those involving satellite reconfiguration and the erection of a multibeam satellite having a large antenna are identified as having the greatest promise.

C-2

Table 3.2.1-1. Communications Satellite Missions Considered

- Space testing of new communications equipment
- Generic hardware testing and deployment
- Satellite maintenance, servicing, and reconfiguration
- Spacecraft checkout and calibration
- Large array deployment and assembly

3.2.1.2 Reconfigurable Satellites

At least ten companies have been granted approval to operate direct broadcast satellite (DBS) systems. A comprehensive domestic DBS system can be assumed to consist of four satellites providing broadcast coverage to the four Conus time zones from four orbit locations. The satellites are identical except for the feed horns and associated feed networks. Spare satellites are placed in orbit to provide coverage in case of failure of one of the operating satellites. Since a single satellite cannot house the four different horns corresponding to all the time zones, two spare satellites are required to ensure continuous coverage: one spare providing backup for the Eastern and Central time zone and one for the Mountain and Pacific time zone. Each spare is equipped with two sets of switchable feed horns and their corresponding feed network. A complete domestic DBS constellation therefore requires six satellites on orbit, with at least two of them possessing a double feed horn system with switching capability.

The existence of a permanent space station might eliminate the requirement for one of the two spare satellites and the requirement for switchable horns. Rather than provide two satellites in orbit, it would be possible to maintain one spare satellite in storage on the space station. This satellite would not be equipped with feed horns and their feed networks, which would be stored separately on the platform. There would be four different feed horn/network assemblies available, and the appropriate one would be installed on the spare satellite when failure of an orbiting satellite occurred. Rapid replacement of a failed or operationally degraded satellite can thus be assured by a single satellite stored on the space station rather than by two satellites in orbit. This would result in a saving of one complete satellite per constellation, plus the added expense associated with the switchable arrays. This saving would be somewhat offset by a charge for storage and servicing at the space station. The magnitude of these savings are discussed in Section 6.0 and Volume 7-2.

During the early years of space station operation, each DBS constellation would consist of four satellites operating in GEO and one spare at the space station. The spare and four feed horn sets would be stored at the station, probably attached externally to the structure. Other configurations might include locating the satellite and associated parts inside an unpressurized hangar, or mounting them on a free flying platform in a nearby orbit from

which they may be retrieved when needed. Later, when reusable OTVs are developed and satellite servicing is proven technology, an entire system might be established with a routine maintenance schedule. A five-satellite constellation would then operate on a regular rotation schedule, with each satellite being brought to the space station for refueling and refurbishing every four years. This concept has the possibility of extending the satellite lifetimes from their current seven years, perhaps to ten or more, thus increasing the system cost-effectiveness.

Manned activities at the space station would be in two periods, both of which involve extensive extra-vehicular activity. These periods can be divided into the following tasks, with manpower projections:

(1) <u>Reception and Storage of Incoming Satellites</u>

It is assumed that this operation will require three technicians over a one day period.

(2) <u>Activation and Launch of Stored Satellites</u>

(1) Personnel required to move satellite from storage position and place it on positioning device (½ day):

1 Technician to operate manipulator device
2 Technicians to secure manipulator to satellite and to assure satellite location on positioner

(2) Personnel required to install horn/feed network assembly (½ day):

1 Technician

(3) Personnel required to carry out antenna range measurements and pre-launch satellite check-out (1 day):

1 RF Technician

1 Technician to operate positioner
1 Data Processing Technician

(4) Personnel required to move satellite from positioning device to launch area

3 Technicians

(5) Personnel required to mate satellite with OTV and to effect launch to geosynchronous orbit (½ day):

3 Technicians

Each satellite requires a total of about 3 technicians over a period of 4 days for receive, reconfigure and relaunch activities. A total period of one week is assumed to allow for possible contingencies such as possible periodic checks while the satellite is in storage. Specialized equipment required at the space station includes a three-axis positioner, a remote manipulator, a precise alignment measurement gear. It is anticipated that only the latter would be unique to this mission.

For mission traffic modeling, it is assumed that one new DBS system is introduced each year from 1991 through 1998. In the first year, four satellites are placed directly into GEO and one is placed on the space station. Beginning in the third year, one satellite per year is transferred from GEO to the space station and replaced by a reconfigured, refurbished, and refueled spare. Assuming a ten-year active lifetime for an individual satellite, the original four active satellites would thus be operational for twelve years, with the original spare good for two years into the next generation.

Traffic from earth to the space station consists only of delivery of one spare for each generation of each DBS system, plus fuel for the satellite orbital stationkeeping and the OTV. Traffic from earth to GEO consists of four satellites in the first year of each generation. Traffic from GEO to the space station consists of one OTV flight per year for each constellation. Thus, for eight systems, one flight per year for eight years is required from earth to the space station, and eight OTV flights per year are required from GEO to

the space station once all eight systems are up. The time-phased traffic model is shown in Section 3.2.1.4 below.

3.2.1.3 Multibeam Satellites

The increased demand for in-orbit transponder capacity has already caused satellite operators to expand from C-(6/4 GHz) to K-(14/12 GHz) band operation. Foreseeing the eventual saturation of K-band capacity, NASA is following the lead of other countries and has started experimental work necessary for commercial exploitation of the 30/20 GHz bands. The expansion to higher frequency bands is not without its cost; however, the one nonnegligible aspect is the uncertainty in transmission quality at these higher bands due to the effects of precipitation. It would, therefore, be highly desirable to increase significantly the usable capacity of the 6/4 GHz band, since such effects are negligible at these frequencies. An order-of-magnitude capacity increase may be obtained by using a large multibeam satellite which would provide Conus coverage with a matrix of spot beams, each having a 3-dB beamwidth on the order of 0.2-0.3 degrees.

Such a system may divide the Conus land area into thirty sections, with the spatial separation large enough to reuse the same frequency thirty times without interference. A repetition factor of seven may be considered feasible, where hexagonal clusters of beams having seven different frequencies would be repeated over the coverage area. Conus coverage by 210 beams, for example, would correspond to 30 clusters with seven frequencies per cluster.

A single such satellite could provide Conus coverage or, alternatively, a pair could provide East and West coverage with a laser or millimeter wave link crossconnecting the two satellites. While such a large satellite would nominally handle a correspondingly large traffic load, the ground installation needed to assure a satisfactory radioelectric link could be of quite modest proportions. Since the satellite would incorporate such features as message demodulation and baseband switching of its digital traffic, it would tend to approach the concept of the switchboard in the sky. It would be necessary of course that the level of switching carried out be reasonably compatible with existing terrestrial facilities, but it can be seen that the tendency would be to pass from the ground network to

the space link at the earliest point possible. There would be a significant economic justification for developing the communications network in this sense.

Initially, it is assumed the satellite antenna will have a diameter of 25m. This provides a 4 GHz beam of approximately 0.2 degrees, which is consistent with an expected pointing error of 0.02 degrees. Larger antenna size and correspondingly narrower beams may be envisaged as expected pointing errors are decreased.

The size of the antenna and the accompanying satellite structure requires that either automatic deployment, manual erection or a combination of the two be employed. It is felt that the last of these options is the most attractive. Automatic deployment would not require manual resources and would best be carried out directly at geosynchronous altitude. However, any malfunction admits no corrective action and very extensive proofing of quite complicated mechanisms must be carried out. It would appear most efficient to rely on the automatic or semiautomatic deployment of certain subassemblies such as the basic boom structure and the antenna framework. These subassemblies would then be joined manually, these functions being of a simple, prekeyed nature. Thermal barriers would then be applied to the assembled spacecraft in structural areas shown to be sensitive to the effects of thermal distortion. Antenna measurements would then be carried out, and final adjustments made in the position of the feed assembly with respect to the antenna structure. It is assumed that many beams would cover regions of low traffic density and, consequently, would be used in a time-shared or scanned mode. Assuming that no more than 70 beams would be active at any given instant, and that each active satellite channel provided 20W output from a solid-state power amplifier, a total solar array power output of 6 kW would be required. This would correspond to an array area of approximately 70 m^2.

It is assumed that the multibeam satellite can be integrated into a single shuttle launch, serviced by a combination of remote manipulators and EVA, and transferred to GEO by a low thrust upper stage booster.

It would appear reasonable to assume that two such multibeam systems would exist in parallel for competitive reasons and to alleviate the effects of a possible, though improbable, catastrophic failure in one of the systems. This would result in two to four such

satellites in orbit in the 2000 and immediate post 2000 time frame. Since experience has shown that communications satellites are unlikely to fail in a catastrophic fashion once they have been successfully put into operation on orbit, it would seem unlikely that an in-orbit back-up would be required. Such satellites provide a great deal of capacity and the gradual failure of individual channels would, for example, tend to increase the waiting time for individual subscribers wishing to gain access to the channels. It would thus be reasonable to assume that the replacement satellite would be launched from the ground at a scheduled date and then stored for a moderate period of time (several weeks or months) before final ascent to geosynchronous orbit.

3.2.1.4 Commercial Communications Missions Summary

It has been assumed that eight reconfigurable DBS systems will be installed in the 1990s. Each system requires the initial, direct launch to GEO of four satellites plus the launch to the space station of one spare and four feed horn arrays. A rotation cycle will be initiated in the third year, with the replacement of one satellite per year. Accommodations required at the space station include a storage berth for up to eight satellites and 32 feed horns, an OTV berthing port, including servicing, integration, and refueling capabilities, positioning and EVA equipment, a remote manipulator, and precise alignment measurement gear. Each satellite servicing event will require three technicians for about one week.

Four multibeam satellites are assumed, with two launches in 1995-1996 and two more in 1997-1998. Each satellite requires storage space, precise alignment and checkout equipment, a remote manipulator, extensive EVA equipment, and a low-thrust upper stage vehicle. Each deployment will require a three-person crew for about ten weeks.

A combined time-phased traffic model for communication satellites at the Space Station is shown in Figure 3.2.1-1.

3.2.1.5 Crew Tasks And Skill Requirements

The tasks for communications support personnel will include the following:

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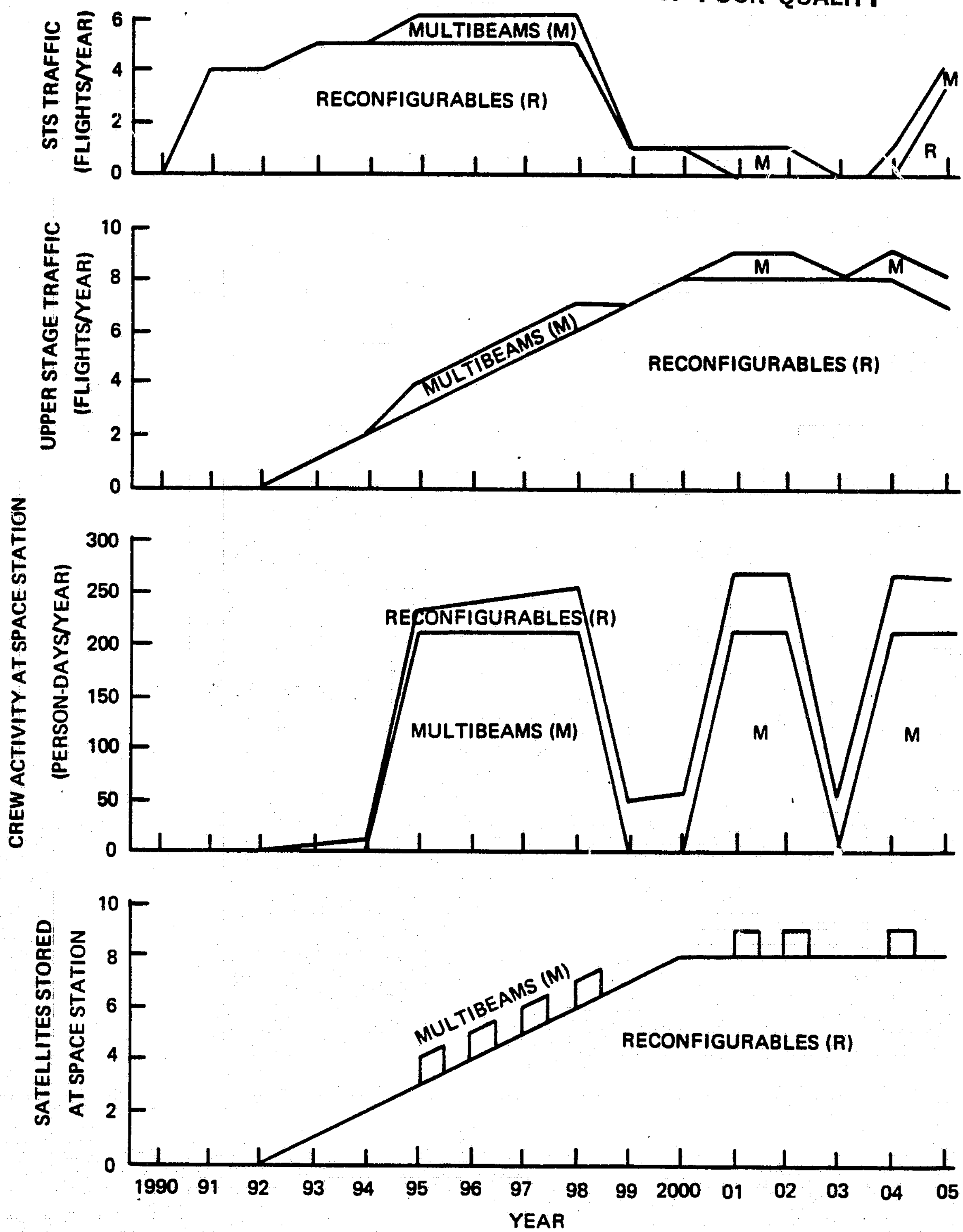

Figure 3.2.1-1 Time-Phased Traffic Model for Commercial Communications Satellites Requiring the Space Station

- Remote control of satellite component deployment
- EVA assembly of large satellite components
- EVA final configuration of stored satellites
- Checkout of satellite functions
- Attachment of satellite to OTV
- OTV launch, maneuvering and docking
- OTV servicing

The required skills include

- High level of EVA qualification
- Basic electronic engineering skills
- High level diagnostic and trouble-shooting skills
- Aptitude for precise remote control operations
- Mechanical aptitude

3.2.2 Commercial Materials Processing Missions

3.2.2.1 Introduction

An orbiting space station offers an environment which is unique for materials processing. The virtual elimination of gravitational forces allows conditions which are unattainable on the Earth for more than a few seconds. The conditions which are most significant for commercial processing of materials in space are those listed in Table 3.2.2-1.

Table 3.2.2-1 Significant Conditions for Space-Based Materials Processing

- o Practical elimination of buoyancy-driven natural convention.
- o Levitation and isolation of large samples for containerless processing.
- o Practical elimination of gravity-induced materials separation.
- o Use of fragile containment structures.

The types of commercial materials which have been investigated in this program are identified in Table 3.2.2-2. This chapter addresses commercial missions in materials processing - it does not address materials processing missions performed solely for scientific purposes. These will be described individually in the following section.

Table 3.2.2-2 Candidate Materials for Commercial Space Processing

- o Semiconductor crystals
- o Biological materials
- o Glasses
- o Metals
- o Ceramics
- o Catalysts
- o Microspheres

3.2.2.2 Semiconductor Crystals

The growth of the electronics and computer industry has been paced to a great extent by progress in the development of pure, uniform semiconductor materials. Electronic circuit speeds increase as the individual circuit elements become smaller, so that they may be more closely packed on a chip. As the individual circuit elements become smaller and smaller, the effect of impurities and crystal imperfections becomes more significant for the proper operation of the chip. The physical size of the chip itself determines the processing capacity. Larger chips would allow larger capacity. Current technology can produce 250K chips. Larger, more uniform chips will likely be capable of a million or more bytes. Larger single semiconductor crystals would also enable much more sensitive infrared detection equipment.

There are several techniques in use for growing semiconductor crystals. Three techniques that might benefit from space-based processing are float zone, vapor-phase transport, and epitaxial growth. Elimination of gravitational forces and thermal convection might allow the growth of very uniform large single crystals. These processes are described below.

<u>Electroepitaxial Growth</u> - One method which is used for growing compound semiconductor crystals is depicted in Figure 3.2.2-1. One chemical species is dissolved in another. The solution is raised above the melting temperature and brought into contact with a seed crystal of the semiconductor being grown. When an electric field is imposed on the melt, the solute ions migrate toward the seed crystal and crystallize with the solvent on the surface of the seed crystal. As long as the melt remains saturated near the growth region, highly stoichiometric crystallization occurs with the process. The electric field forces convection of the solute to the crystal growth layer so that this region remains saturated as uniform crystals are grown.

The electric current densities required for current-controlled electroepitaxial growth are in excess of 10 A/cm^2. (Ref. 1) This current flows through the melt and the crystal. Resistive heating and Peltier cooling at the interface cause temperature gradients in the melt. In a gravitational field these temperature gradients would cause thermal convection, which would destroy the uniformity of the crystal. Thermal convection does not occur under microgravity conditions. Therefore high current densities are allowed in the microgravity environment of space and, since growth rate is linearly proportional to current density, rapid growth of large, uniform, compound semiconductor crystals is allowed.

Microgravity Research Associates, Inc. is developing the electroepitaxial growth process for space-based growth of gallium arsenide (GaAs) crystals. GaAs is a superior semiconductor to silicon in several areas. It has a much higher switching speed, lower power requirements, lower heat loss, and higher temperature resistance. All of these advantages combine to allow gallium arsenide to have a higher circuit element density with greatly enhanced processing speeds and reduced cooling requirements. Furthermore, GaAs is much more resistant to radiation than is silicon, allowing its use in nuclear, space, and military environments where silicon-based semiconductors would quickly degrade. Finally, GaAs emits coherent light, which allows its use in optical processing equipment.

Ground-based GaAs growth experiments have been performed with low current densities and small dimensions to suppress thermal convection, but real experimental verification of the concept must await spaceflight. Microgravity Research Associates has recently signed a Joint Endeavor Agreement to develop the electroepitaxial growth process for gallium arsenide.

<u>Vapor Phase Epitaxial Growth</u> - One method which is currently used for growing semiconductor crystals involves transport of the crystalline elements from a source to a growth crystal in the vapor phase, as depicted in Figure 3.2.2-2. To grow crystals with this method, a polycrystalline source of material is heated in the presence of a gaseous transport agent. A chemical reaction between the source and the transport agent results in exclusively gaseous products which are removed from the source. The growth crystal is located at the other end of the growth ampoule, and is maintained at a lower temperature than the source material. The gaseous products are transported down the temperature gradient to the growth crystal, where they undergo the reverse chemical process and condense into the original chemical product, in monocrystalline form. (Ref. 2.)

The crystal uniformity of the product reflects the uniformity of the vapor phase. In full gravitational fields, thermal convection of the vapor disturbs the uniform flow and limits the crystal perfection. Thermal convection does not occur to a significant degree in microgravity, so more uniform crystals can be made at higher growth rates.

This process is being developed at Rensselaer Polythechnic Institute for growth of large, monocrystalline, compound semiconductors. Previous experiments have been performed with germanium and group VI compounds. Future plans call for vapor phase expitaxial growth of large, ternary semiconducting compounds, such as $Hg_x Cd_{1-x}Te$. These could be used as infrared detectors, with a response function which can be selected by choosing x.

A series of crystal vapor growth experiments are scheduled on the MEA-A facility aboard the orbiter. The first scheduled flight is on STS-6. The crystal material on this flight will be germanium-selenium. All subsequent flights, beginning in April 1984, are planned with mercury-cadmium-telluride.

<u>Float Zone Processing</u> - A common method for growing crystals on Earth is by float zone processing. A long rod of semiconductor material is heated in a localized region by an annular, coaxial heat source. The heat source moves very slowly longitudinally along the rod, melting a narrow band along the rod, which is subsequently recrystallized as the furnace moves past.

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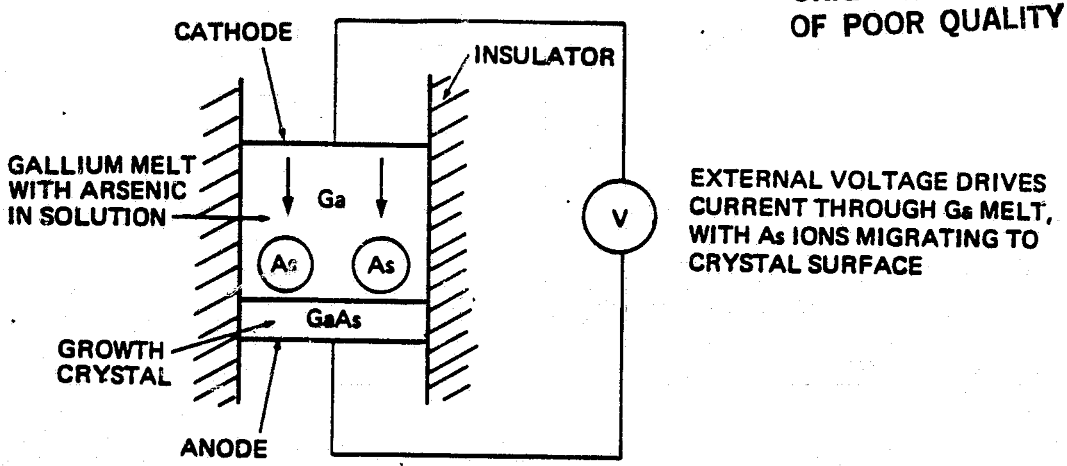


Figure 3.2.2-1 Electroepitaxial Crystal Growth

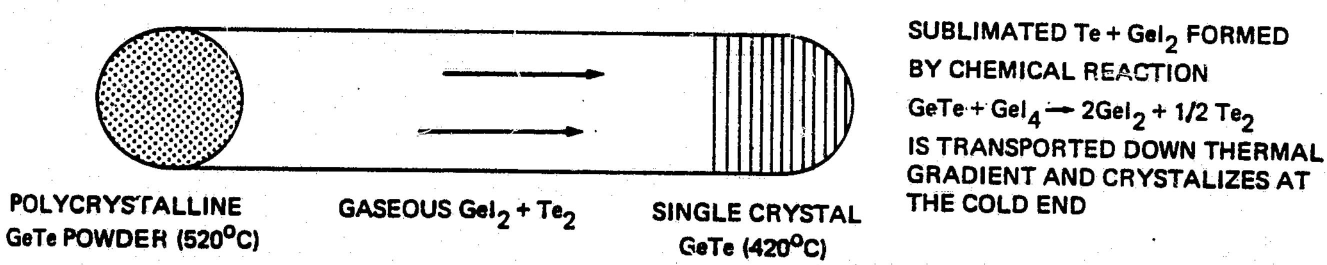


Figure 3.2.2-2 Chemical Vapor Transport Epitoxial Crystal Growth

The thickness of the crystal and the speed of the furnace is limited on Earth by gravity acting on the molten float zone. A large float zone would deform and tend to flow in full gravity. Under microgravity conditions, however, larger float zones may be possible, allowing larger crystals to be made more rapidly. This process is being investigated for growing silicon crystals by Westec under contract to NASA. A test flight with a number of small silicon rods (5-7 mm diameter, 15 cm zone pass) is planned in the orbiter.

Crystal Growth Accommodations - Semiconductor crystal growth in space requires substantial electric power levels for long periods of time. Orbit and pointing characteristics are unimportant, provided that the system is relatively stable to acceleration. The acceleration limit is not known at this time, but is believed to be in the range from 10^{-5} to 10^{-3}g. High temperatures are required to melt the source crystals in each case. Data and crew requirements are not yet well known, but are not likely to be excessive, i.e., will probably not drive the space station design.

Semiconductor crystal growth development might occur in four distinct phases: preliminary testing in STS orbiter flights in the near term, STS-based commercial flights on a small scale, space station-based large scale process development, and free flying platforms which take on a character of an orbiting factory. These four phases would set the stage for large scale processing of GaAs crystals grown by the electroepitaxial growth process.

A space station provides the opportunity to do substantial process development in reasonable times. Standard crystal process development equipment onboard the space station falls into three categories: crystal growth furnace, materials storage, and laboratory diagnostic equipment. It is likely that the furnace will be custom built for each process to be developed on the station, i.e., each user would use a furnace design specifically for that approach. For the sake of estimating physical parameters, we assume a furnace mass of 10 kg for each kilogram of crystal to be grown at one time, excluding the replaceable crystal and its holder. The volume of a crystal furnace would be 10-20 liters for each kilogram of crystal.

It seems reasonable that materials will be brought from Earth already loaded into cartridges for insertion into the furnace. The space station must therefore provide storage for these

cartridges before and after processing. If we assume a cartride mass of 15 kg for each kilogram of crystal, then the mass to be stored is 15 times the mass to be processed between resupply missions. Storage racks used to be provided for this purpose, which can be shared among the users.

The laboratory diagnostic equipment can be shared by all semiconductor crystal growers if the space station users' fee would somehow amortize this common equipment. This equipment would include the following: a Hall aparatus, including the magnet and measuring equipment (~100 kg, 1m^3); some arrangement for measuring deep levels of photoluminescence (~20 kg, 0.1m^3); an acid bath for etching (10 kg, 0.01 m^3); a cutting saw (10 kg, 0.02 m^3); a polisher (10kg, 0.02m^3); a contact fixer (10 kg, 0.01m^3); and a good optical microscope (100 kg, 1m^3). All together, the total mass on the space station for an adequate electronic crystal diagnostic laboratory is not anticipated to weight more than 500 kg and would not require more than 5 m^2 wall space, or 20 m^3 volume, including access. The only apparatus that might use substantial electrical power is the Hall equipment if an electromagnet is used, which might require 2-3 kW. A permanent magnet would obviate this requirement.

A projection of the potential demand for space-provided gallium arsenide is shown in Figure 3.2.2-3. In consideration of the early stage of development of GaAs technology, and allowing for equipment development cycle times, it is projected that equipment using GaAs ICs will not see volume production until 1985. Market projections for emerging technologies and the growth of GaAs markets are estimated in Table 3.2.2-3.

There is little doubt that market demands will emerge for space-produced electronic materials in addition to GaAs. For example, mercury cadmium telluride and indium phosphide are likely candidates. While none have yet been identified with the broad range of market applications and potential bulk requirements of GaAs, emerging demands for specific requirements, such as detectors effective in particular frequency ranges, will lead to space-production of a growing number of crystal materials. It is expected that these other materials, in total, will represent not more than two or three percent of the total of space crystal production by 1990. However, increasing market demand is forecast to raise this percentage to 10% of total of space produced electronic materials by 1995 and to 15% by the year 2000.

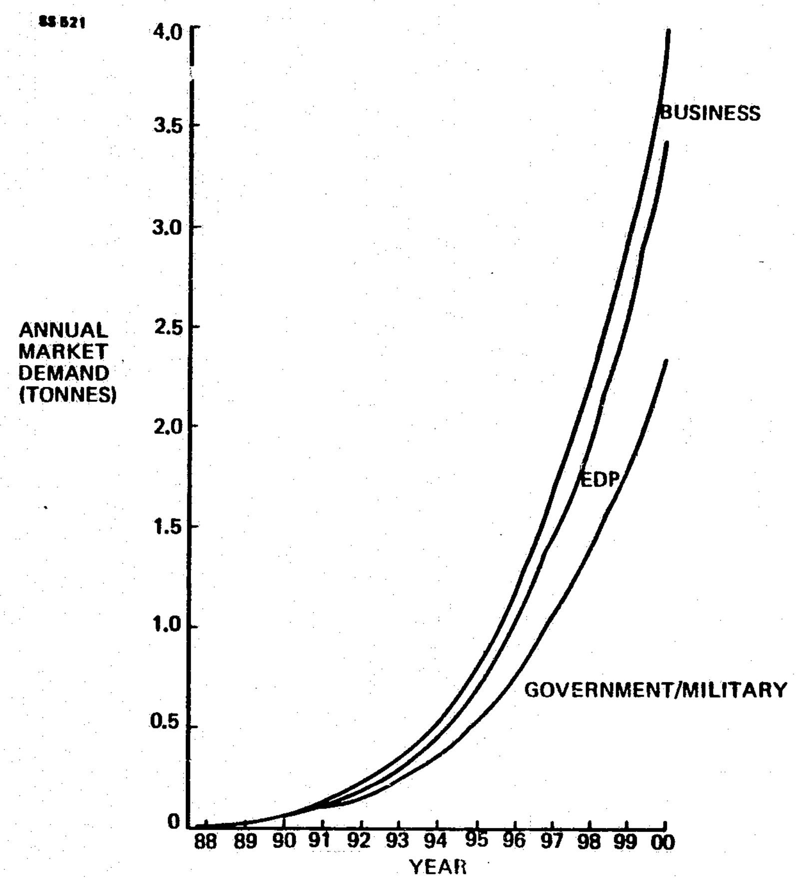


Figure 3.2.2-3. Space-produced Gallium Arsenide Market Projections

Table 3.2.2-3. Projected Demand For Space-Produced Gallium Arsenide

Market Category	1990	1995	2000	2005
Government/Military	\$117M	\$405M	\$1650M	\$2660M
Electronic Data Processing	12	126	1130	1820
Communications	5	46	124	200
Business	34	39	154	248
Instrumentation/Industrial	2	9	21	34
TOTAL	\$170M	\$624M	\$3059M	\$4962M

As the market and the growth process develops, the STS traffic pattern shifts. A summary of the projected traffic model through the year 2000 is shown in Table 3.2.2-4. A growth rate of 10%/year is assumed after 2000. The crystals will start out being grown on one week orbiter sortie flights, with the furnace being carried along on each trip. As soon as a free flyer becomes available, the process will be transferred to the free flyer, which provides power to the furnaces simultaneously (60 kW), thus the three furnaces would be loaded at the start of the orbiter mission and returned one week later with the same flight. If the free flyer is power-limited, the furnace will be operated sequentially and recovered on a later flight. When the space station becomes available, the manufacturing site then moves to the station, where it remains until the power demand for a single crystal type exceeds 20 kW. After 1993, a crystal growing platform is placed in orbit every two years, with the incremental power shown in Table 3.2.2-4, and resupply missions fly from the space station to the free flyers by TMS.

Once the space station becomes available, the furnaces will be left on the space station. The industry demand is expected to evolve from two-inch to three-inch wafers in 1994, and to five-inch wafers in 1997. One spare is always maintained at the space station, with old furnaces being returned to Earth as they become obsolete. The electrical power demand grows rapidly near the end of the century. It may be expected that the additional power sources beyond some basic level will be supplied by the crystal growth user.

3.2.2.3 Biological Materials

The usefulness of a wide range of biological materials depends on the degree to which they can be concentrated and purified. Current processes for separating these materials are often limited by convection. The materials are purified by flow processes in aqueous solution. The sharpness of the flow patterns is degraded by thermal and buoyancy-driven convective forces. This lack of resolution limits the purity of the separation products. Elimination of convective forces can greatly enhance the sharpness with which different materials can be separated, as well as increasing the concentration of the product. The improved separation of pharmaceuticals that can be achieved in space offers a near-term commercial product of space-based materials in processing. Two processes have been considered for this applicaton: continuous flow electrophoresis and isoelectric focusing.

Table 3.2.2-4 Projected Crystal Growth Traffic

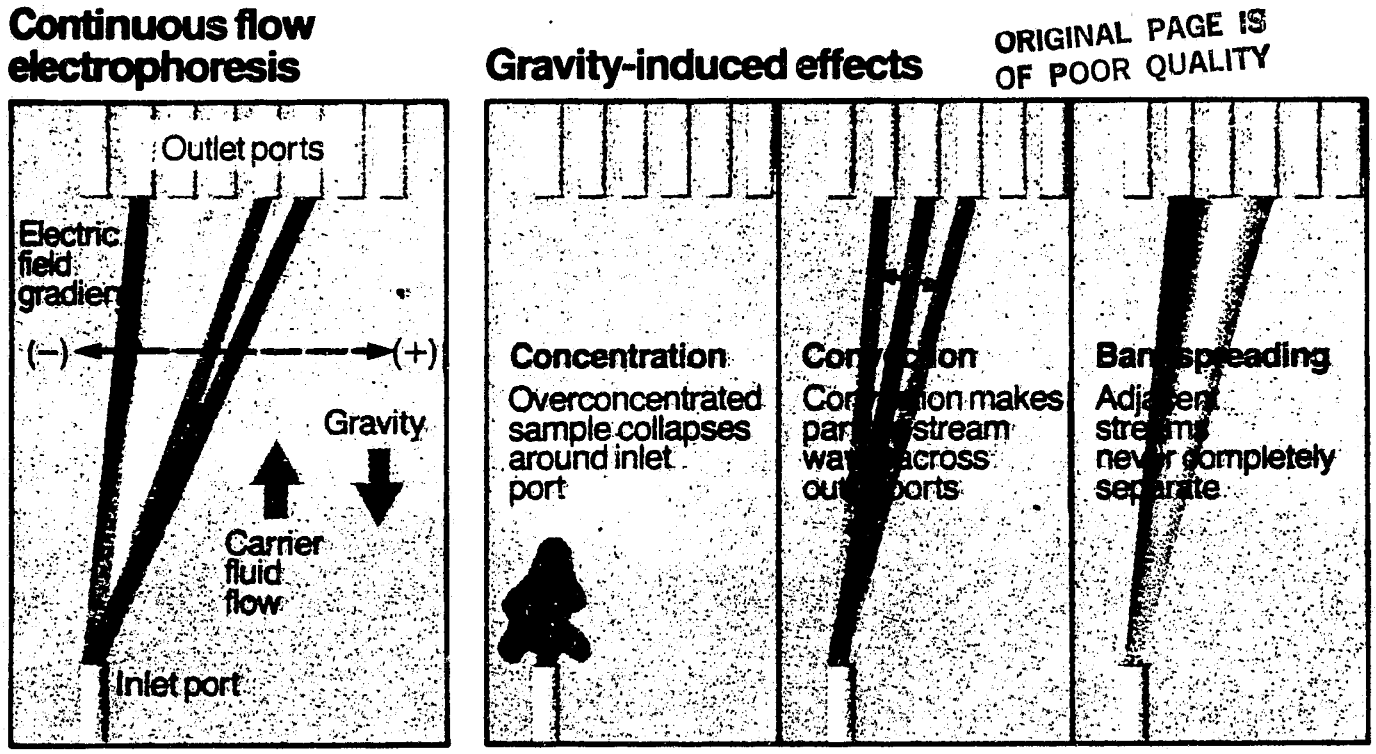
Year	Flight Mode	Crystal Mass Grown Kg	No. of Furnaces In Orbit/ Crystal Size	Electric Power kW	Mass Up kg	Mass Down kg	No. of Flights
1988	Orbiter Sortie	12	1-2"	12	1,300	1,300	1
1989	Orbiter Sortie	30	1-2"	12	3,900	3,900	3
1990	Orbiter Sortie	68	1-2"	12	7,800	7,800	6
1991	Orbiter-serviced free flyer	115	3-2"	20	5,200	5,200	3
1992	Space Station	213	2-2"	20	2,950	1,000	2
1993	Space Station	438	2-2"	20	5,030	3,920	3
1994	Space Station serviced free flyer	713	2-3"	20	7,640	7,220	3
1995	Space Station serviced free flyer	1,194	3-3"	40	12,500	10,400	3
1996	Space Station serviced free flyer	1,998	3-3"	60	18,100	17,200	3
1997	Space Station serviced free flyer	3,125	5-5"	80	34,550	26,850	3
1998	Space Station serviced free flyer	4,500	5-5"	120	46,150	45,750	4
1999	Space Station serviced free flyer	5,938	6-5"	120	60,650	59,250	5
2000	Space Station serviced free flyer	7,975	9-5"	160	97,950	92,000	6
		26,309			303,720	281,790	45

Continuous Flow Electrophoresis - Biological materials, such as proteins, enzymes, and cells often have a surface electric charge distribution which causes them to respond to an electric field. When placed in a fluid medium with an electric potential difference between two ends, these materials will be transported to one end. The speed with which the materials travels varies according to the charge distribution. Different materials have different mobilities. This difference in mobility allows different materials to be separated according to their electric charge distribution.

Figure 3.2.2-4 shows conceptually how a continuous flow electrophoresis apparatus works. A liquid buffer solution is located between two electrodes. A potential difference between the electrodes establishes an electric field in the solution. Those components of the material to be separated which have the highest electric mobility move the fastest to one electrode. After some time in the field, the various components of the material are separated. On Earth, buoyancy-driven convection caused by concentration differences and by density changes due to Joule heating limits the size of the sample which can be separated. Typically, samples of less than 0.1 ml are separated on a porous gel plate by a batch process where the samples are frozen into place after some period in the chamber. The small size of the apparatus limits the separation resolution, while convection considerations limit the possible purity of the product.

Elimination of gravity-driven convection in space allows a continuous flow electrophoresis process (CFE). In CFE, the buffer solution flows continually perpendicular to the electric field, while the sample is also added continuously to the processing chamber. Much larger volumes of sample material can be separated in this manner with much larger processing chambers. As shown in the figure, the product materials are collected in distinct collection vials. The continuous processing, larger volume, longer time in the electric field, and lack of convection allows much higher materials throughput, higher yield from a given quantity of sample material, finer separations, and higher purity of product material than can be achieved on Earth.

Space-based electrophoresis experiments were first attempted during the Apollo program, with unclear results due to poor experiment design. The first successful results were obtained in the Apolly-Soyuz spacecraft. In this experiment, in which material was



In continuous flow electrophoresis, biological materials suspended in a carrier fluid are separated by an electric field. July's Shuttle experiment (top) separated a lab-standard mix of egg and rat albumin, plus six proteins from a cell culture product. Eliminating gravity effects boosted flow rate some 400 times, purity 5 times. Five more Shuttle experiments are planned for 1983–84.

Figure 3.2.2-4: Continuous Flow Electrophoresis (Ref. 3)

separated by a batch process in a small column and frozen in place, the degree of separation of human fetal kidney cells was higher than any previous results (Ref. 4). As a result, distinctions were identified between three different cell types that had not previously been identified. This development program has now accelerated with the introduction of the STS. A partnership has been formed to develop a commercial CFE process under a Joint Endeavor agreement with NASA. Results of experiments conducted on STS-4 were highly reassuring, and plans are proceeding to build a commercial prototype demonstration (Ref. 5) with five c biter flights scheduled in 1983 (Ref. 6).

Isoelectric Focusing - A similar technique which has been proposed for space-based separation of biological materials is isoelectric focusing. The buffer solution establishes a pH gradient when the electric field is imposed. Since the mobility of the material to be separated varies as the pH of the buffer, the sample material moves in the direction of the gradient to a particular value of the pH: the isoelectric point. The products are well-focused within the pH gradient and then collected as in continuous flow electrophoresis. This method may have potential for even finer resolution than electrophoresis, but has not yet been demonstrated in space since the ph environment of isoelectric focusing is extreme, it is not suitable for processing of living cells. Three experiments are scheduled for hormone purification in the orbiter mid-deck in 1984. (Ref. 6).

The requirements for space station accommodation of biological separations processes are generally lighter than for semiconductor growth, especially since the temperatures are very low. Power requirements especially are eased. The need for refrigeration to preserve samples imposes special thermal control constraints. The larger materials throughput may also impact the space station storage volume requirements.

The continuous flow electrophoresis process is currently the most advanced MPS program. The success of the Apollo-Soyuz experiment, an extensive ground-based research program, and especially the STS-4 mission has resulted in optimism that the concept is understood well enough to do engineering design. McDonnell-Douglas Astronautics and Ortho Pharmaceuticals Division of Johnson and Johnson have five orbiter flights scheduled in 1983. The developers now plan to fly a production prototype electrophoresis unit in 1985, which will produce the first commercial product. The development program apparently calls for a

fleet of unmanned, shuttle-tended free-flyers beginning in 1986. (Ref. 7). Although specific plans are proprietary, it seems reasonable to project attaching these automated factories to a space station when one becomes available. This would allow the use of space station power and control systems, as well as facilitating materials storage, delivery, and retrieval by operating through a single central base.

A large number of biological products have been proposed for space station separation. A recent forecast of the potential for space-produced pharmaceuticals indicated the following numbers of patients could be helped annually. See Table 3.2.2-5 (Ref. 8).

A number of assumptions have been made in estimating the physical requirements that biological separations imposes on space station design. First, since a normal adult has about 2 ml of Islets of Langerhans, of which 60% are beta cells, and patients produce adequate supplies of insulin with as much as an 80-90% deficiency in Islet mass, it is estimated that a patient dose will be 0.24 ml/patient. It is assumed that the feedstock is about 1% concentration of beta cells grown in culture from fetal pancreatic material. It is further assumed that the feedstock is transported in the orbiter with a 1.5:1 mass ratio of container/structural material to feedstock. The required launch rate is thus calculated to be 0.036 kg/patient. With these assumptions treating 3.2 million patients per year requires a total launch rate of 115,000 kg/year, or 4 dedicated orbiter flights per year, just for beta cell electrophoresis.

Next, we assume by this author's subjective assessment that the estimate for interferon in Table 3.2.2-5 is high by a factor of five, and that unidentified other uses will add 50% to the annual patient load, so that 14 million patients/year can be treated by space-processed pharmaceuticals by the year 2000. If the required dose and feedstock concentration is comparable to that estimated for beta cells, the required orbiter traffic is 17 flights/year. At this traffic volume, it is likely that strong demand will be placed on the government to allow a privately-owned fleet of launch vehicles. Beyond 2000, a steady flight rate of 20/year is assumed. To satisfy the demand for space-processed pharmaceuticals, an electrophoresis platform is launched every three to four years, beginning in 1990. The platform is serviced from the space station with a TMS, while the space station is used for materials storage, laboratory analysis, and process development.

Table 3.2.2-5 Estimated Electrophoresis Product Demand

Bioproduct	Annual Patient Load
Pancreatic beta cells	3.2 million
Epidermal growth factor	1.1 million
Human growth hormone	0.85 million
Antitrypsin	0.5 million
Interferon	20 million

Space station accommodations for pharmaceutical processing would include a number of processing facilities, a control laboratory, storage racks, and crew accommodations. Assuming that electrophoresis technology develops to accommodate a flow rate of one liter/hour in a $2m^3$ unit, then 40-50 units would be required in the processing facility, occupying 200-250 m^3 when access volume is considered. These 40-50 units would provide separations for a number of different pharmaceuticals and different commercial users, say 5-10 processes. The control laboratory would be for process control of the electrophoresis units, quality control of the product, and repair of the process units. It is believed that this can be a shared multi-user facility, of roughly 100 m^3, with fluid, thermal, and electrical control systems and biological laboratory equipment. Storage racks for about two weeks throughput, or about 25 m^3, would be required. The materials need to be chilled to about 4^oC during storage, both before and after processing.

Such a traffic volume for a variety of users would require substantial crew sizes. Assuming five users each with a crew of three working on a two-week rotation cycle, plus an additional crew of three for housekeeping and equipment maintenance results in an eighteen person crew for pharmaceutical processing, and about 500 passenger flights per year.

3.2.2.4 Glasses and Fibers

The reduced gravity in orbit allows materials to be processed in a container-free environment. Fluids in microgravity conditions form large globules that "float" in space without spilling or breaking up. This allows the possibility of melting and resolidifying materials without the materials even contacting the container walls while in the molten state. This property might be useful for a variety of material classes, the most hopeful class being high quality and unique glasses.

There are two features of glass processing that make the containerless processing available in microgravity especially attractive. First, the high melting points of most glasses makes them extremely reactive in the molten state. The chemical reactivity causes the molten glass to interact with the container walls, resulting in impurity introduction into the melt. In gravitational processing, these impurities are unavoidable. Since the optical and mechanical properties of glass are very sensitive to impurity levels, chemical reaction with

the crucible often seriously degrades the glass quality. Containerless processing should eliminate impurity generation by this mechanism and allow more perfect optical properties and stronger glasses.

Second, glasses are distinguished from metals and other solids by their lack of crystalline structure. Under gravitational conditions, molten glass as it cools tends to solidify around nucleation sites at the crucible walls, because the walls are cooler than the interior of the melt and the impurity level is higher there. Crystals tend to grow around these nucleation sites, resulting in a higher degree of crystalline structure than is desirable. In a containerless environment, a higher degree of supercooling is possible without the onset of heterogeneous nucleation, thus allowing a lower level of crystalline structure and therefore more ideal glassy properties. Homogeneous nucleation also allows the processing of glasses with different chemical mixes than are possible on earth. So containerless processing allows more ideal glassy properties and should allow unique glasses to form which cannot be duplicated on earth.

A facility for processing glass in space will be dominated by the furnace. The furnace has two primary functions: a programmable power supply for heating and a positioning control system for holding the melt in place. The material sample would likely be heated by absorption of some sort of electromagnetic radiation: most likely in the microwave or infrared frequency range. Other heating mechanisms that have been proposed include electron beam impingement and solar concentrators. Although the melting temperature of most of the candidate glasses is very high, the actual heating power load can be quite low because containerless processing eliminates conductive and convective heat losses. A kilogram sized specimen of silica glass can be melted in a half hour with about 1 kW heating source. Heat losses can be further minimized by using infrared reflecting walls. A glass specimen would be heated to a few degrees superheat and then rapidly cooled to promote homogeneous nucleation.

The heated samples tend to drift in space due to orbital dynamics and g jitter if they are not actively held in place. They can be positioned by several means. They can be attached to a sting which holds them in place by surface tension. This method may result in neterogeneous nucleation and conductive heat loss to the sting. If the samples can be allowed to

come in contact with a cover gas, it can be held in place by acoustic pressure driven by loudspeakers in the walls of the chamber. Truly containerless processing in a vacuum can be achieved by positioning the sa. ɩle with either electromagnetic or electrostatic forces.

Uses for space-processed glasses will likely be restricted to those for which high purity is essential. These might include optical fibers with high transmissivity which would require fewer repeaters than current systems, and allow faster, more efficient data transmission. Optical fibers are finding increasing use where faster, more compact data transmission is desired and where resistance to electromagnetic interference is demanded.

Specialty glasses which might benefit from space processing include optical filters, where particular spectral bands are to be suppressed, and lead glasses, as for viewing radioactive substances. Another common use is for laser host materials, such as neodymium-doped YAG. It seems likely that many more applications would develop once space-based processing demonstrates the formation of glass forms that could not be reproduced on earth. Optical glasses for lenses and mirrors might be processed in space with very low crystallization, which would provide higher quality image processing.

No containerless processing of glasses has yet been done by the United States in space. Projections of future demand have been based on expected properties of containerless-processed glass - not on actual experimental results. Until experiments have been completed and the results evaluated, it will be difficult to foresee a commercial market. A more plausible development scenario would start with at least a four or five year experimental research program where different glass materials would be formed by different cooling process and examined. An orderly research program would establish the properties of different materials, the effects of experimental conditions such as sample temperatures, cooling rates, and positioning methods, and the efficiency of a variety of heating and cooling techniques. Once this basic research program has advanced our knowledge of space-processed glasses and their fabrication techniques, it may be easier to identify commercial markets with some understanding of costs and benefits.

Assuming a basic research program begins soon and is supported at a reasonable level on a continuous basis, commercial production might begin by 1990. An estimate of the rate of

production of space-produced glass was based on a recent estimate of market projections of optical fiber components through 1990 (Ref. 9), and on the assumptions that space processing will offer significant improvements in fiber quality. The breakdown of market potential and growth rate is given for the period of 1990-2000 in Table 3.2.2-6. After 2000, a growth rate of 10% per year is assumed. The fiber production rate was estimated by assuming that 25% of the component cost is that of the fiber, and that 40% of the fiber cost is for STS transportation. Transportation costs are assumed to be $2650/kg in 1990, with a 5%/year inflation rate thereafter. The resulting estimate of the production rate of space-processed optical fibers is shown in Figure 3.2.2-5.

Without a specific process for producing containerless-processed optical fibers, it is difficult to project space station accommodations. Reasonably consistent assumptions can be made, however, to make rough order-of-magnitude estimates. Here we assume that a single containerless glass furnace has an electric heater and a radiofrequency positioning system. We further assume that a molten source of glass has a mass on the order of 1-3 kilograms and that this source is fed continuously and 100 fibers can be pulled simultaneously from the source and stored on spools. If the pullers draw 10 um diameter fibers at 1 m/s with an 80% availability, then a single such furnace would produce 435 kg/yr while consuming about 50 Watts of electric power. Assuming that the glass is packaged into the orbiter with a 1.5:1 structure ratio, the demanded throughput by 2000 requires 340 furnaces.

With these somewhat speculative estimates, the physical accommodations on the space station can be scaled. The electric power requirements grow steadily with each flight, in modest increments, to a level of 17 kW by 2000. Assuming each furnace is contained in a 0.2m square base by 0.5m high, then by 2000 the required volume is 6.8m^3. At 50 kg/furnace, the mass on the space station is 17 tonnes. About 100 m^3 of storage volume would be required.

3.2.2.5 Commercial Materials Processing Summary

At the current stage of development, it is impossible to predict accurately which materials processes will be successfully commercialized, or what the commercial market volume will be. It does appear that three of the most promising general areas of interest are

Table 3.2.2-6 Market Assumptions For Space-processed Optical Glass Fibers

Category	1990 Projection (Ref. 9)	Saturated Market Demand For Space-Processed Fibers	Market Saturation Period	Projected Growth Rat 1990-1995	1995-2000
	$M	$M	yr	%/yr	%/yr
Telecommunications	456	250	6	40	30
Government/Military	212	75	10	40	30
Computers	74	50	4	60	40
Industrial	64	6	10	20	15
Cable TV	21	15	3	20	15
Satellite Ground Stations	21	15	3	20	15

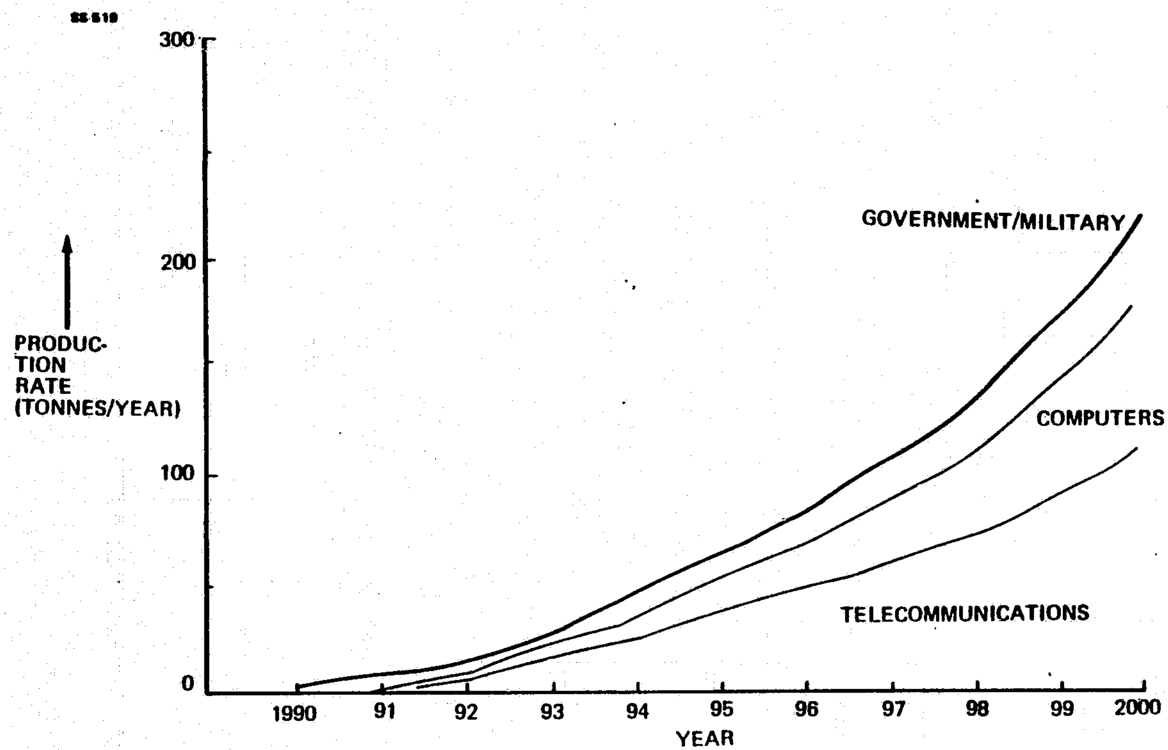


Figure 3.2.2-5. Estimated Space-PRocessed Optical Fiber Production Rate

semiconductor crystals, high purity biological materials, and containerless - processed glass products. A mission model has been described based on current projections of demand growth for specific products in each area. Only an active experimental program can verify the improvement in product quality which is expected in microgravity. Each commercial user assumes risks associated with several key issues: 1) that the space-processed materials quality may be less than anticipated; 2) that a competitive Earth-based technology might develop to achieve comparable quality at lower cost; 3) that the market for high quality product may be less than projected; and 4) that once a commercial enterprise is undertaken, the government policy regarding costing, government-industrial relations, or program continuity might present impediments to successful commercialization. In the case of pharmaceutical products, the issue of licensability of the new products adds another uncertainty.

Undaunted by these uncertainties, it is possible to estimate space station accommodations requirements with the assumption that, if one or more of the products described does not result in a commercial market, then other as-yet unidentified products will be more successful. Figure 3.2.2-6 depicts the space station mission model through the year 2000 with these caveats. A uniform growth rate of 10%/year, typical of a mature industry, has been taken for the period after 2000. It is seen that the mass, volume, and STS traffic will be dominated by the pharmaceutical uses. This is a result of the low concentration of the material in the culture before electrophoresis, the large number of consumers, and the substantial laboratory necessary to provide the quality control necessary for purifying a product for human consumption. The space station power, on the other hand, is dominated by the energy intensive processing of semiconductor crystals.

The needs of the commercial materials processing users will have a major impact on space station facilities. Table 3.2.2-7 summarizes the accommodation requirements. It would be difficult to satisfy these needs if the costs were met by a constrained government budget. The fact that these users are private, profitable companies provides an obvious financial solution. With the magnitude of risks involved in a start-up operation of a revolutionary process, it is difficult to envision private funding of an initial space station. Once an initial space station were placed in orbit, supported by government funding, the growth accommodations can be provided by private funding. These accommodations would include additional power and thermal rejection systems, additional production facilities, additional crew support systems, and expanded transportation capabilities.

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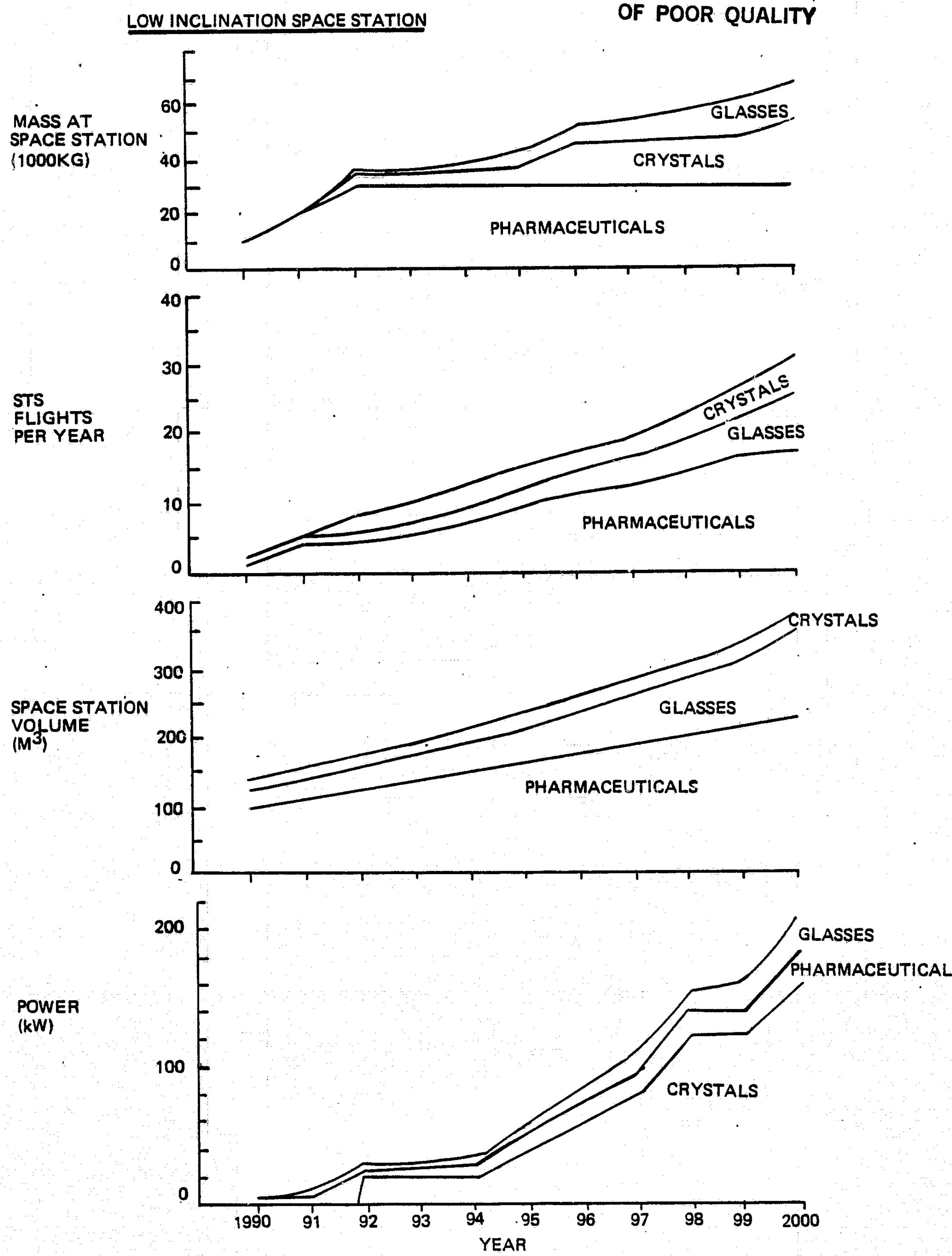

Figure 3.2.2-6. Time-phased Accommodations Requirements for Commercial Materials Processing

85 510

Table 3.2.2-7. Commercial Configuration Characteristics.

COMMERCIAL MISSIONS	ORBIT		PROGRAM				SIZE/ WEIGHT		INTERFACE										OPERATIONS			ENVIRONMENT			
	INCLINATION (DEGREES)	ALTITUDE (KM) – (A) ANY, (L) LOW	SCHEDULE (YEAR)	NUMBER OF FLIGHTS	DURATION (MONTHS)	UPPER STAGE	VOLUME (M^3)	WEIGHT (KG)	POWER AV./PEAK (KW)	HEAT REJECTION MIN/MAX	ORIENTATION - (I) (S) (E) (A) ANY	POINTING/STAB ARC SEC/ARC-SEC/SEC	DATA	BERTHING PORT	INTERNAL	EXTERNAL	S.S. MANIPULATOR	PLATFORM (P) HANGAR (H)	IVA	EVA	FREE FLYER SERVICING (S), REMOTE (R)	LOW CONTAMINATION	"0" G	MICRO METEROID PROTECTION	RADIATION PROTECTION
CONTINUOUS FLOW ELECTROPHORESIS	28.5	A	90/00	100	12		325	30	5	MAX	A				X				X						
GLASS PROCESSING OPTICAL FIBERS	28.5	A	90/00	37	12		100	30	0.6	MIN	A				X				X						
VAPOR EPITAXIAL CRYSTAL GROWTH	28.5	A	90/95	8	10		0.5	3	10	MAX	A				X				X						
FLOAT ZONE CRYSTAL PROCESSING	28.5	A	92/96	4	10		30	0.3	20	MAX	A				X				X						
ELECTROEPITAXIAL CRYSTAL GROWTH 2	28.5	A	92/93	5	10		20	1.5	20	MAX	A				X				X						
ELECTROEPITAXIAL CRYSTAL GROWTH 3	28.5	A	94/96	9	10		20	4	40	MAX	A				X				X						
ELECTROEPITAXIAL CRYSTAL GROWTH 5	28.5	A	97/00	17	10		50	12.5	120	MAX	A				X				X						
RECONFIGURATION COMMUNICATION SATELLITE	GEO		91/05	45	0.23	X	50	1.8	3.5	MAX	A							H	X	X					
MULTIBEAM COMMUNICATION SATELLITE	GEO		95/99	4	7	X	50	5	0		A							H	X	X					

To use semiconductor crystal growth as a model, the initial space station would be developed and built at NASA expense, with adequate provisions to supply 20 kW, to operate two 2" crystal furnaces, to house a materials diagnostic laboratory, and to provide for a small crew. Some form of pricing policy would allow NASA to recover actual operating costs. As the market for space-produced semiconductors grows, additional companies might elect to enter this field. They would do this by paying their share of the additional operating costs, and providing their own equipment. Particular hardware will be owned by individual companies, while common systems might be shared. Two examples of shared systems are power and lab facilities. When additional power is required, the crystal growing companies would provide this power and associated systems at their own expense. Thus, in time, the crystal growing facilities will have been built with increasing shares of private capital. Laboratory facilities might be provided by the government with the understanding that the continued technology development is in the national interest, and the basic government-supported research can be done with these facilities. If necessary, private users might be charged an equipment rental fee.

3.2.2.6 Crew Tasks and Skill Requirements

During the developmental phases of the materials processing the space station personnel will directly monitor the processes and immediately analyze the output of each batch of materials. They will evaluate the characteristics of the material and make necessary modifications to the processing of the next batch in a series.

The personnel involved in the development of materials process require the following skills:

- o Advanced understanding of the research and processes involved.
- o High level analytic skills.
- o Basic electronic technician skills.
- o Basic diagnostic and troubleshooting skills.
- o Intermediate mechanical skills.

Once a materials processing methodology has matured the processes in space will be mostly automated. Further refinements to the processes will generally be made by researchers on

the ground interleaving trial batches of materials in with regular production batches. These trial batches will then be examined after return to earth. The requirements for space personnel will mostly be for maintenance, modification and repair of the automated equipment.

The space station personnel involved with mature materials processing will need the following skills:

- Advanced mechanical maintenance skills.
- Advanced electronics technician skills.
- High level diagnostic and troubleshooting skills.
- EVA qualified.
- Advanced training in electrical, electronic, and mechanical systems used in the materials processing production.

3.2.2.7 References for Section 3.2.2

1. L. Jastrzebski, et al., "Liquid-phase electroepitaxy: Growth Kinetics," J. Appl. Phys. 49 (12), December 1978.

2. R. J. Naumann & H. W. Herring, Materials Processing in Space: Early Experiments, NASA SP-443, Washington, D.C., 1980.

3. C. Watts, "Space Factories a Long Way Off," High Technology, November/December 1982.

4. Apollo-Soyuz Test Project: Summary Science Report, Vol. I, NASA SP-412, Washington D.C., 1977.

5. "Prototype Plan Follows Space Processing Test," Av. Week & Space Tech., 19 July 1982.

6. Processing Materials in Space, MFS-25667, Summer 1982.

7. J. C. Lowndes, "Fairchild/NASA Agree on Leasecraft," Av. Week & Space Tech., 19 October 1982.

8. C. Covault, "Payload Tied to Commercial Drug Goal," Av. Week & Space Tech., 31 May 1982.

9. J. Tsantes, "Fiber-optic Demand is Set to Soar, "Electronic Business, April 1981.

3.2.3 Commercial Earth Observations Missions

Earth observation has been a major application of orbiting satellites since the early days of space flight. Civil use of satellites in weather prediction, cartography, and resource assessment has become commonplace in our government institutions. The presence of man provides a greatly enhanced capability to perform many earth observation missions. The special skills for this activity are summarized in Table 3.2.3-1. Man's adaptability allows him to respond to a wide variety of needs, especially to images which were not predicted when instruments were designed. Man's capabilities for pattern recognition allow him to distinguish subtle changes from surrounding areas. The ability to distinguish thousands of hues obviates the need for instruments with many, many spectral channels. Together, these abilities for pattern recognition and spectral resolution assist man to do what he probably does best - to interpret information and draw conclusions in real time. This enables him to decide where to look and what instruments to use for the best results. Finally, his memory of previous patterns and changes over time allow him to make predictions and respond to cognitive features without losing information due to a data glut.

Commercial involvement in earth observations from a space station will first be in the areas of food production, range land management, forest management, geology through mineral exploration, and prediction and assessment of man-made and natural disasters. Crop management will improve in soil moisture, soil temperature, water requirements, water forecasting, fire detection, disease and infestation detection, and in crop production estimates. Mineral exploration will be aided by highly selective multispectral panoramic imaging of several scales. Hazard warning systems for potential disasters such as earthquakes, severe storms, floods, fires, and volcanoes will be valuable to the government and post-disaster assessment will be valuable to commercial entities with large land holdings, such as in open ranges and forestry. Manned earth observation missions with commercial potential are summarized in Table 3.2.3-2.

Although a number of potentially commercial earth observation missions have been described, it is likely that the first manned observation missions will be carried out for the government, with equipment developed primarily at government expense. Essentially the same equipment can be used for scientific and applications missions for the government as

Table 3.2.3-1. Benefits of Man for Earth Observation

- Adaptability
- Pattern recognition
- Spectral resolution
- Image recall
- Inductive reasoning
- Hypothesis formulation and testing
- Data value discrimination

Table 3.2.3-2 Manned Earth Observation Missions With Commercial Potential

1. Forestry: Timber stand estimation and health assessment
2. Geology: Mineral location
3. Agriculture: Crop monitoring
    a. Disease
    b. Water requirements
    c. Nutrients
4. Ship monitoring and traffic lanes (air and sea)
    a. Location
    b. Traffic
    c. Threats
    d. Currents
5. Fisheries
    a. Migration
    b. Ocean temperature, currents
    c. Nutrient streams
    d. "Red tide"

well as for commercial missions for private industrial organizations. Since no single user has been identified which would require a dominant fraction of the total time available with any instrument, it seems likely that commercial earth observation would be performed with government-furnished equipment aboard the space station and paid for by a user charge. Since the equipment and facilities will be already present at the space station, special accommodations for commercial use are not considered here. Rather, the reader's attention is directed to Section 3.1.5 above.

Crew Tasks and Skill Requirements - The crew tasks and skill requirements for commercial earth observation missions will be similar to those for earth environment scientific missions. Earth observation skill requirements include:

- Superior visual feature detection and recognition skills.
- Basic electronic engineering skills.
- High level diagnostic and trouble shooting skills.
- Aptitude for precise remote control operations.
- EVA qualified.
- Mechanical aptitude.
- Advanced training in earth environment sciences.

3.2.4 Industrial Services

3.2.4.1 Introduction

Industrial services are defined to be hardware and sevices that aerospace contractors could/would supply for the space station program that would be developed using company resources and would be sold or leased to commercial and institutional space station system users and to NASA. Table 3.2.4-1 lists the scope of potential industrial services considered here. We have selected crew selection and training and in-space operational services for discussion herein.

Table 3.2.4-1. Potential Industrial Services

Hardware

Teleoperator Maneuvering System
Space Platform
Perigee Kick Motor
External Tank Propellant Storage Depot
Spacecraft Bus
Logistics Module

Operational Services - On Ground

* Crew Selection and Training
  Logistics Module Turnaround
  Space Station Ground Control Center Operations
  Space Station Module Ground Processing

Operational Services - In Space

* Satellite Assembly Operations
* Satellite Maintenance Operations
* Space-Based Upperstage Vehicle Turnaround Operations
* Space Station Facility Operations

* Industrial services discussed herein.

3.2.4.2 Crew Selection and Training

The concept for this industrial service is diagrammed in Figure 3.2.4-1. NASA and the contractor would write a crew selection and training requirements document which would be the basis on which other contractors would formulate crew selection and training programs. NASA and the contractor would be charged with certifying the training programs, facilities, and staffs. Various contractors would recruit, select, and train the space station specialists in their company-owned facilities using their company's training staff. Each space station crewman would be sent to NASA to receive generic training applicable to all the crew, e.g., zero-g habitation. The trained and certified crewmembers would then be hired by NASA, space station customers, or other industrial service contractors.

The crew selection and training program would encompass various functional specialities; including space mechanics, payload specialists, and spacecraft systems operators. We will focus on the space mechanic selection and training. We have selected this particular potential industrial service for discussion because we have been in direct contact with an organization that wants to provide this service. (See Volume 7-2).

The existing curriculum for aircraft mechanic students, as defined by Federal Aviation Regulation Part 147, has been in effect for almost 13 years and while it is dated, does provide a good basis for the training of spacecraft mechanics. This curriculum base can be modified to be the basis of a curriculum for the training of spacecraft mechanics.

It would not be practical to utilize the existing aircraft mechanic curriculum for spacecraft mechanic instruction without some major changes. The entire aircraft mechanic curriculum would have to be examined by a panel of experts. Those subject-areas of value would be modified for spacecraft mechanic training. While only half of the existing aircraft mechanic curriculum would be of use to a spacecraft mechanic curriculum, the instructional format has proven itself and readily can be adapted for spacecraft mechanic training.

In addition to the maintenance, repair and servicing courses that need to be taught to spacecraft mechanic students, the process of actually living and working in the hostile environment of space is absolutely essential. The actual instruction of living and working in

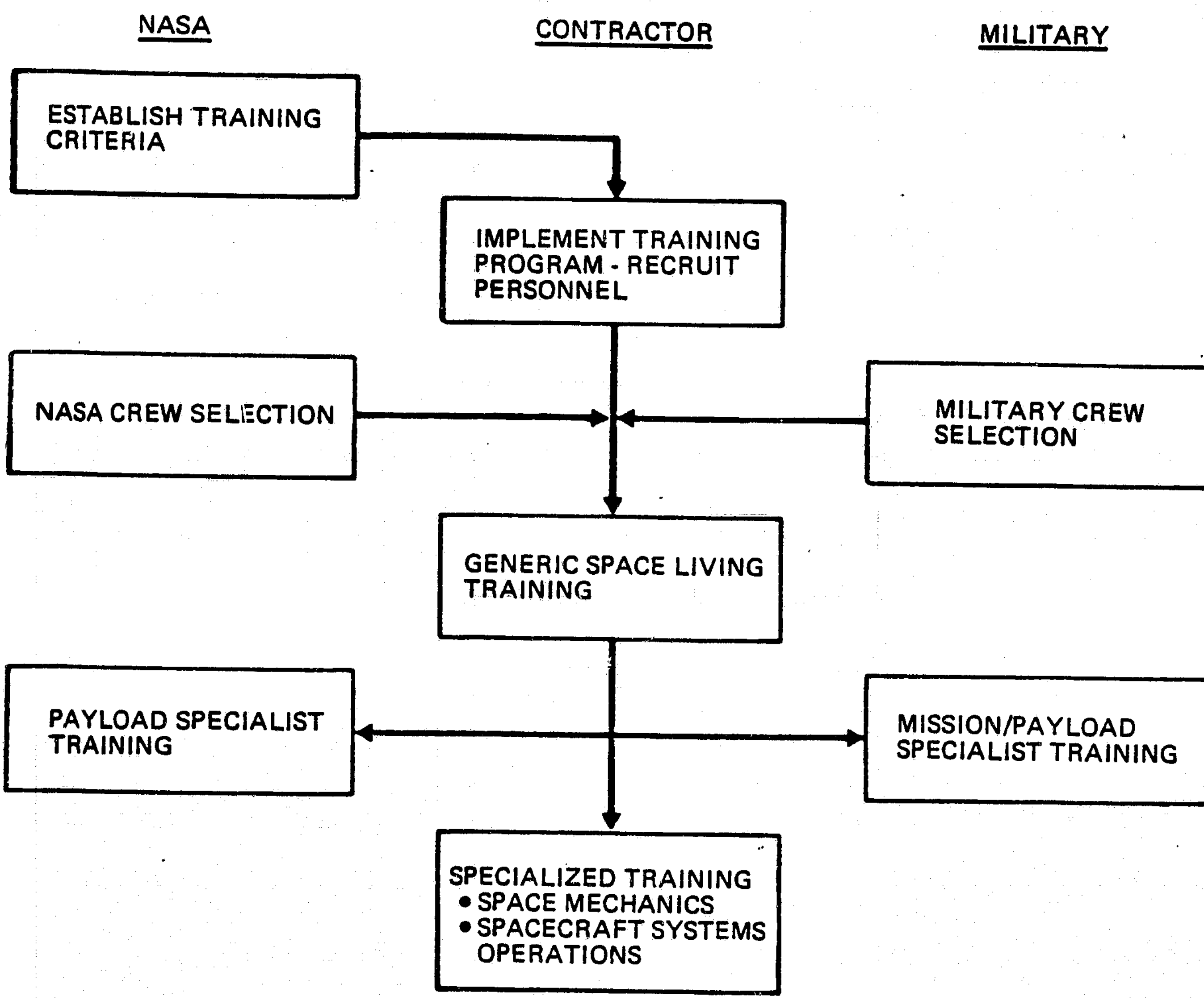

Figure 3.2.4-1. Industrial Crew Selection

space will probably be a separate, specialized course that all space workers will undergo. However, there should be a strong emphasis on space safety throughout the entire spacecraft mechanic training program. This emphasis should be coordinated with the curriculum on "Space Environment Safety" thereby providing a smooth transition from spacecraft mechanic trainees to qualified space workers. Additionally, each phase of spacecraft mechanic training should emphasize the necessary safety precautions peculiar to the individual spacecraft systems, i.e., rocket engines, life support systems, etc.

As a means of reducing the expense of developing the needed curriculum for spacecraft mechanic training, NASA should appoint a Spacecraft Mechanic Curriculum Coordinator to work with them and industry. The Aviation Maintenance Foundation has substantial expertise available in curriculum development and can provide the necessary coordination. such coordination will bring together specialists from the aviation and aerospace industries, Aviation Maintenance Technician Schools and government agencies (including NASA). The combined efforts of these specialists will provide the best curriculum available for the training of spacecraft mechanics. Once spacecraft mechanics actually begin working in space, their activities should be closely monitored to allow for continued improvement of the curriculum. This continuing improvement will provide for better space safety which, in itself, will help in the continued advancement in space exploration.

Once the spacecraft mechanic curriculum has been developed by the specialists and approved by NASA, a test-bed for the curriculum implementation should be selected. Since aviation maintenance technician schools already have a great majority of the equipment needed for proper instruction, two or three schools should be selected to begin the initial training phases. These initial phases will cover the theory of spacecraft maintenance as well as the integrated safety training. After the spacecraft mechanic students have completed their training in spacecraft maintenance, repair and servicing, they will transfer to NASA's own facilities. At these facilities, the spacecraft mechanic students will undergo the training needed for living and working in space.

An evaluation of the different test-beds should be made to determine which one is the most effective. Once this evaluation has been made, standardized curriculum implementation can be developed thereby providing an additional safety margin for space workers. It should be

understood that there will be a necessity for standardization in several areas for the space workers' safety, i.e., technical jargon, safety procedures, etc. Such standardization will have to be considered as the respective curriculums are developed.

3.2.4.3 In-Space Operational Services

The space station mission is to provide construction, servicing, flight support, and experimental capabilities to commercial and institutional users. As a national facility, especially an expensive one that will likely use advanced technology, it will be developed and built under NASA direction. Once operational capability is achieved, however, program decisions must be made regarding the appropriate roles of NASA, other government agencies, and private industry. NASA's traditional role has been that of a national research and development agency. If it is to continue to have R&D as its primary function, then it will have to turn over routine operations of the space station to another government organization or to a commercial contractor.

The role of coordination of space station operations is an opportunity for an industrial service contractor. One contractor would have primary responsibility for space station operations, in a manner similar to the Shuttle Processing Contractor approach under consideration at Kennedy Space Center. Under such a contract, NASA's role would be to establish the requirements and develop mission technology planning, provide for the use of NASA-owned facilities and the STS, and provide the funding. The space station operations contractor would then be responsible for implementing the space station operations program with minimal NASA oversight and with proper incentives to control costs. Other prime NASA contracts might be awarded for satellite servicing and upper stage vehicle turnaround operations. These will each be discussed briefly below.

Areas for which the space station operations contractor would be responsible include task planning, orbit maintenance, communications, plant operations (i.e., electrical power, environmental control, water management, etc.), food preparation, housekeeping, and equipment maintenance. It is possible, even likely, that some of these functions may be subcontracted.

The housekeeping contract, for example, could be administered in much the same way as janitorial and food services are handled for commercial airlines. A housekeeping crew would routinely fly to the space station to clean all air and water filters, replace necessary consumables, remove wastes, and perform routine janitorial services. This contracting approach would free up the space station crew for more mission-intensive activities. Currently, it seems hard to imagine highly-specialized mission specialists spending most of their time performing mundane housekeeping chores. During initial space station operations, while the crew is small, this would be done by a ground-based crew which visits periodically. They would ride along on an orbiter flight to the space station and perform their housekeeping tasks while the orbiter is being off-loaded. The housekeeping crew would then return to earth with the orbiter. As the crew grows, at some time it will become advisable to transfer the housekeeping crew to space-based residence. This crew would then reside on the space station and rotate with other crew members to earth on a regular schedule. At about this time, it will be appropriate to include food preparation as a contractor activity.

Satellite servicing and upper stage vehicle turnaround are other likely areas for industrial contracts. A satellite servicing contractor would be responsible for routine maintenance, resupply, and repair of government-owned satellites. This contractor would store the required tools, fuels, and equipment on the space station. Three operational modes of servicing are envisioned: 1) The satellite to be serviced is transported to the space station and docked, with operations being performed in a hangar. The satellite is then transferred back to its operational orbit. 2) Operations are performed remotely, using a Teleoperator Maneuvering System. 3) The satellite is serviced in its operational orbit by astronauts who rendezvous with either a manned sortie vehicle or the orbiter. An additional activity of this contractor may be to collect space "junk" and either boost it to a safer orbit or return it to earth. It seems likely that privately-owned satellites would be serviced by the satellite owner, but this responsibility can also be contracted, provided issues related to liability and insurance can be resolved. Another contractor role would be to provide upper stage vehicle turnaround, including propellant transfer, payload integration, launch and recovery services. These functions may be performed by individual contractors or subcontractors, or they may be performed by the crew selection and training contractor described earlier.

3.3 TECHNOLOGY DEVELOPMENT MISSIONS

3.3.1 Introduction

The purpose of this section is to summarize the selection and development of the Technology Development Missions for the space station. First, technology development objectives and requirements for the space station were defined. Then, these objectives and requirements were used to provide an organized and uniform means of conceiving and defining candidate technology development missions. These candidate missions were then subjected to several screening processes to eliminate duplicate missions, assign missions into appropriate mission categories, and delete unneeded missions. The remaining valid missions were then put through a cost and priority analysis. This analysis resulted in a fiscally constrained technology development mission schedule. These scheduled missions were then manifested on the space station. These anlyses and scheduling activities also drove out a need for a general purpose laboratory facility at the space station. The technology development mission data base was then utilized to identify architectural drivers for the space station.

3.3.2 Candidate Missions

Candidate technology development mission inputs were received from each NASA Center. Individual experts and authorities identified for each candidate mission were contacted and additional data and study information was collected to help in the analysis of these missions. In addition to this activity a comprehensive literature search and review was conducted to identify other candidate missions. NASA literature as well as other contractors' documents and university studies were surveyed to locate technology development missions that had not been previously identified. Contact was made with several universities to obtain further information on several technology development mission areas. Boeing's extensive experience in space studies was utilized to identify technology development missions and to evaluate the large collection of missions that had been identified through this process. The final seventy-six technology development missions, as shown in Table 3.3.1-1, reflect the background, experience, expertise and interests of the users, items identified in the literature, Univerity contacts, and our expertise. This selection of missions reflects our interpretation of the direction and intent of the space station.

Table 3.3.1-1. Technology Development Mission Summary

MISSION		TYPE	ACCOMPLISH IN: SCIENCE AND APPLICATIONS	ACCOMPLISH IN: COMMERCIAL	ACCOMPLISH IN: COMBINED WITH	REJECT NO MISSION OR TECHNOLOGY
BACX2000	EARTH OBSERVATION INST DEV MAPS		0451			
BACX2001	PASSIVE MW RADIOM (LSS-3)	10				
BACX2002	EARTH OBSERVATION INSTR DEVELOP		0451			
BACX2003	SATELLITE DOPPLER METEOR RADAR		0003			
BACX2004	MICROWAVE REMOTE SENS TECH		0453 0453			
BACX2005	EARTH FEATURE IDENTIFICATION		0451			
BACX2006	ZERO-G BROMINE PHASE SEPARATION					ACCOMPLISHED ON SHUTTLE
BACX2007	EARTH BOUND ORIENTED INST DEV		0401			
BACX2008	LARGE SOLAR COLL (LSS-6)	10			2035	
BACX2009	SPACE COMPONENT LIFETIME TECH	15				
BACX2010	MATERIALS & COATING TECHNOLOGY	10				
BACX2011	LIQUID DROPLET RADIATOR	16				
BACX2012	ION THRUSTER EFFECT ON LEO POWER	11				
BACX2013	CREW SYSTEMS-EMESIS STATION	15				
BACX2014	DISHWASHER/CLOTHES WASHER	15				
BACX2015	CRYOGENIC FLUID STORAGE TECHNOLOGY				2064	
BACX2016	CRYOGENIC LIFETIME TECHNOLOGY				2064	
BACX2017	FLUID MANAGEMENT TECHNOLOGY					ACCOMPLISHED ON SHUTTLE
BACX2018	FIRE SAFETY TECHNOLOGY	15				
BACX2019	TETHER DYNAMICS TECHNOLOGY	15				
BACX2020	LARGE SPACE POWER SYSTEM TECH	11				
BACX2021	TEST SOLAR-PUMPED LASERS				2056	
BACX2022	LASER-TO-ELECTRIC ENERGY CONVERS				2056	
BACX2023	SOLAR-SUSTAINED PLASMAS	11				
BACX2024	LOW COST MODULAR SOLAR PANEL TECH	11				
BACX2025	LASER COMM TRACKING DEVELOP	12			2056	
BACX2026	MULTI-FREQ HIGH GAIN ANTENNA	12				
BACX2027	SINGLE CRYSTAL RHODIUM WAFERS	10				
BACX2028	LASER PROPULSION TEST				2056	
BACX2029	HABITABILITY CRITERIA VALIDATION	14				
BACX2030	MANIPULATOR CONTROLS TECHNOLOGY				2059	
BACX2031	SATELLITE SERVICING TECHNOLOGY				71-73	
BACX2032	OTV SERVICING TECHNOLOGY				63-70	
BACX2033	SPACECRAFT STRAIN & ACOUSTIC EMI				2035	
BACX2034	SPACECRAFT HANGAR (LSS-2)	10				
BACX2035	MATERIALS EXPOSURE LAB	10				
BACX2036	PRECISION OPTICAL SYSTEM (LSS-4)	10				
BACX2037	CONST & STORAGE FAC (LSS-1)	10				
BACX2038	LARGE STRUCTURES TECH EXPERIMENT					
BACX2039	ATTITUDE CONTROL-SYSTEM IDENT				2031 2034 2001 2036	

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Table 3.3.1-1. Technology Development Mission Summary (Continued)

MISSION		TYPE	ACCOMPLISHED IN: SCIENCE AND APPLICATIONS	ACCOMPLISHED IN: COMMERCIAL	ACCOMPLISHED IN: COMBINED WITH	REJECT NO MISSION OR TECHNOLOGY
BACX2040	ATTITUDE CONTROL-ADAPTIVE CONTROL				2001	
BACX2041	ATTITUDE CONTROL DIST CONTROL				2001	
BACX2042	ZERO-G ANTENNA RANGE COMM EXP				2001	
BACX2043	DYNAMICS OF LIGHTLY LOADED STRUCT				2001	
BACX2044	SPACECRAFT MATERIALS TECHNOLOGY				2035	
BACX2045	SPACECRAFT CONTROL TECH DEV.				2001	
BACX2046	ADVANCED CONTROL DEVICE TECH DEM				2001	
BACX2047	THERMAL SHAPE CONTROL TECHNOLOGY				2001	
BACX2048	ACTIVE OPTICS TECHNOLOGY				2036	
BACX2049	GEODESIC SPHERICAL STRUCTURES					X
BACX2050	LARGE SPACE STRUCTURE TECHNOLOGY				2037 2034	
BACX2051	CONTROLLED ACCELERATION PROPULSION					X
BACX2052	TELEOPERATOR REAL TIME COMM					X
BACX2053	LARGE ANTENNA DEVELOPMENT					X
BACX2054	FAB OF LIGHTWEIGHT CRYO HEAT PIPE					X
BACX2055	ADV ADAPTIVE CONTROL TECH DEMO					X
BACX2056	SOLAR PUMPED LASERS	16				
BACX2057	MATERIALS PROC TECH-PROC & TECH			1005 1006		
BACX2058	ELECTROPHORESIS SEPARATION			1005		
BACX2059	MANIPULATOR DEVELOP & TEST FACILITY	15				
BACX2060	SHOWER STATION	15				
BACX2061	TRASH MANAGEMENT	15				
BACX2062	CRYOGENIC FLUID STORAGE TECH.				2063 2064	
BACX2063	PROP TRANSFER TECH DEMO (OTV-1)	15				
BACX2064	PROP STORAGE TECH DEMO (OTV-2)	15				
BACX2065	RNDZVX, DCKG, BRTHE TECH DEMO (OTV)	15				
BACX2066	OTV MAINT TECH DEMO (OTV-4)	15				
BACX2067	PAYLOAD/OTV INTEG TECH DEMO (OTV)	15				
BACX2068	CLOSED ECLS FOR SPACE STATION	15				
BACX2069	SOLAR ARRAY ADDITION TECH DEMO	15				
BACX2070	FORMATION FLYING TECH DEMO (SS-2)	15				
BACX2071	SATELLITE ASSY TECH DEMO (SS-3)	15				
BACX2072	ON-BOARD SAT SERV TECH DEMO	15				
BACX2073	INSITU SAT UNMANNED SERV TECH DE	15				
BACX2074	SURFACE INTERACTION W/RCS PLUME	13				
BACX2075	ROBOTICS	15				
BACX2076	COMPOUND SEMICONDUCTOR CRYSTALS		1003 1004			

SS-737

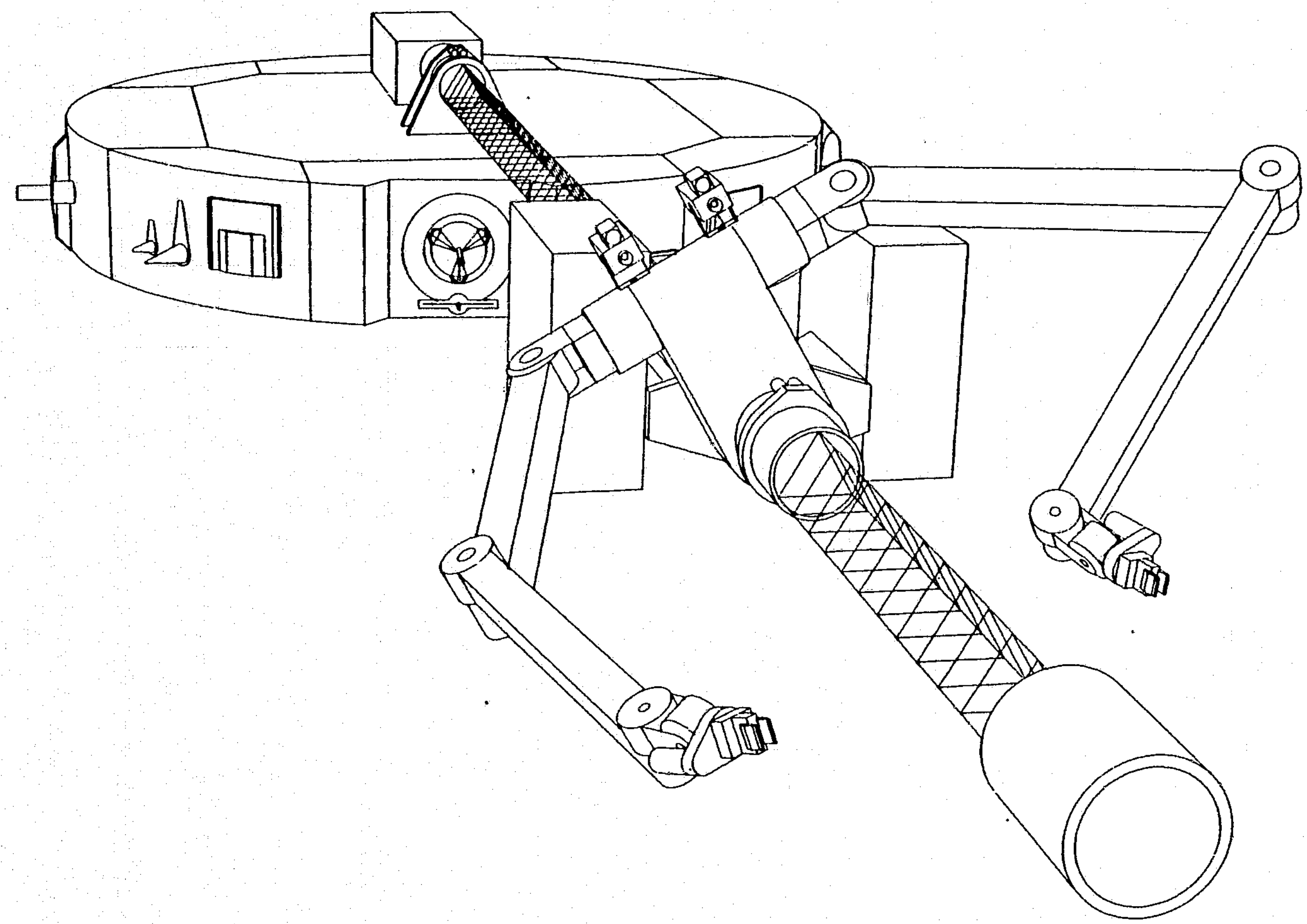

Figure 3.3.2-4. Spacecraft Robotic Servicer

In order to quantify each mission a preliminary mission data form was prepared, including Boeing-specific input data and available cost data. This information was then fed into a computer data base and this system used to update and track the status of each mission.

Using the advanced input program a mission data form was generated for each technology development candidate mission. These forms were utilized to screen each mission. Figure 3.3.2-1 is a sample of the Boeing computer generated form BACX2037 Construction and Storage Facility (LSS-1) with Figure 3.3.2-2 preliminary drawings showing it stowed, deployed and attached to the space station. Figure 3.3.2-3 is another example of the computer-generated forms BACX2075 Robotics including specific input data with Figure 3.3.2-4 preliminary drawings showing the robotics package deployed on a TMS. The complete set of computer-generated technology development missions data forms plus preliminary drawings, cost data and other relevant information are included in Volume 7, Section 3.

3.3.3 Mission Screening

The diverse categories and large number of inputs for the technology development mission has created overlap and duplications within these missions. This diversity and number of inputs presented a problem of organizing the wide variety of suggested missions. The NASA Mission Data Form categories Table 3.3.3-1 were utilized to provide the framework for organizing these missions into a logical order.

Table 3.3.3-1. BACX2XXX Technology Development

10	Materials and structures
11	Energy conversion
12	Computer Science and Electronics
13	Propulsion
14	Control and Human Factors
15	Space station systems/operations
16	Fluids and thermal physics, physics and chemistry

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PAYLOAD ELEMENT NAME: CONST & STORAGE FAC (LSS-1)
CODE: BACX2037

CONTACT
Name: RICHARD GATES
Address: BOEING AEROSPACE CO, PO BOX 3999, SEATTLE, WA 98124

Telephone 206/773-2020

TYPE
( ) Science and Applications (Non-comm.)
( ) Commercial
(X) Technology Development
( ) Operations
( ) Other
( ) National Security
Type number (see table A) 10

Importance of the Space Station to this Element
1 = Low Value, But Could Use
10 = Vital
Scale = 8

STATUS
( ) Operational ( ) Approved ( ) Planned (X) Candidate ( ) Opportunity

Desired First Flight, Year: 1990 Number of Flights 1 Duration of Flight, Days 365

OBJECTIVE
LARGE SPACE STRUCTURES TECHNOLOGY DEMONSTRATIONS (DEPLOYMENT AND ASSEMBLY , SUBSYSTEM INSTALLATION AND CHECKOUT, DEMONSTRATION OF MAN'S ROLE AND CAPABILITIES IN SPACE). FOLLOWING THE TDM, THIS STRUCTURE WILL SERVE AS A PERMANENT SPACE STATION FACILITY.

DESCRIPTION
THE CONSTRUCTION AND STORAGE FACILITY IS A LARGE PLANAR, DEPLOYABLE TRUSS ATTACHED TO THE SPACE STATION AT A BERTHING PORT. ADDITIONAL STRUCTURAL SUPPORT STRUCTURES WILL BE ATTACHED TO PROVIDE STRUCTURAL ATTACHMENTS FOR PAYLOADS AND OTHER MODULES TRANSPORTED TO THE SPACE STATION VIA STS.

ORBIT CHARACTERISTICS
Geosynchronous Orbit ( ) Yes (X) No
Apogee, km 500 Perigee, km 500 Tolerance + -
Inclination, deg 28.5 Tolerance + -
Nodal Angle, deg Any Ephemeris Accuracy, m
Escape dV Required, m/s

POINTING/ORIENTATION
View Direction ( ) Inertial ( ) Solar ( ) Earth (X) Any
Truth Sites (if known)
Pointing Accuracy, arc-sec 0.00 Field of View (deg)
Pointing Stability (Jitter), arc-sec/sec 0.00
Special Restrictions (Avoidance)

POWER
( ) AC ( ) DC

	Power, W	Duration, Hrs/Day
Operating	0	0.00
Standby	0	0.00
Peak	0	0.00
Voltage, V	0	Frequency, Hz 0

(X) Continuous

DATA/COMMUNICATIONS
Monitoring Requirements:
( ) None (X) Realtime ( ) Offline ( ) Other:
( ) Encription/Decription Required
( ) Uplink Required: Command Rate (KBS): 0 Frequency (MHz): 0.00
( ) On-Board Data Processing Required
Description:
Data Types: ( ) Analog ( ) Digital Hours/Day 0.00
Film (Amount): 0 Voice (Hours/Day): 0.00
Live TV (Hours/Day): 0.00 Other:
On-Board Storage (Mbit): 0.00
Data Dump Frequency (Per Orbit) 0 Downlink command rate: 0
Recording Rate (KBPS) 0.00 Downlink Frequency (MHz): 0.00

THERMAL
( ) Active (X) Passive
Temperature, deg C Operational Minimum 0 Maximum 0
Non-operational Minimum 0 Maximum 0
Heat Rejection, W Operational Minimum 0 Maximum 0
Non-operational Minimum 0 Maximum 0

EQUIPMENT PHYSICAL CHARACTERISTICS
Location ( ) Internal (X) External ( ) Remote
Equipment ID/Function ( ) Pressurized (X) Unpressurized
Length: 2.50 meters Width: 2.50 meters Height: 1.00 meters (Stowed)
Length: 26.00 meters Width: 12.00 meters Height: 3.50 meters (Deployed)
Launch mass, kg: 2000 Return mass, kg:
Consumable Types
Acceleration Sensitivity, (g) min: 0.00E+00 max: 0.00E+00

CREW REQUIREMENTS
Crew Size 0
Skills (See Table B)

Task Assignments

Skill	11	12	13			
Level	3	3	3			
Hours/Day	0.00	0.00	0.00			

EVA (X) Yes ( ) No Reason CONSTRUCTION Hours/EVA 120

SERVICING/MAINTENANCE
Service: Interval 0 days Consumables 0 kg
Returnables 0 kg Man hours required 0.00
Configuration Changes: Interval 0 days Man/Hours Required 0.00
Deliverables 0 kg Returnables 0 kg

SPECIAL CONSIDERATIONS/See instructions
AS A TECHNOLOGY DEMONSTRATION MISSION (TDM), REALTIME MONITORING (TV) AND DATA MEASUREMENT EQUIPMENT (STRUCTURAL ACCURACY, DYNAMICS, THERMAL DEFLECTIONS) WILL BE REQUIRED. FOLLOWING THE TDM, PERMANENTLY MOUNTED TV AND AUXILIARY LIGHTING ARE REQUIRED.

Figure 3.3.2-1. BACX 2037 Contstruction and Storage Facility (LSS-1)

Boeing-Specific Input Data

MISSION TYPE	OPS CODE
Free Flyer	
( ) Not Serviced	F
( ) Remote TMS	FT
( ) Remote Manned	FM
( ) Serviced at Station (TMS Retrieved)	FST
( ) Serviced at Station (Self-propelled)	FS
Platform Based	
( ) Not Serviced	P
( ) Remote TMS	PT
( ) Remote Manned	PM
( ) Serviced at Station (TMS Retrieved)	PST
( ) Serviced at Station (Self-propelled)	PS
Other	
(X) Space Station Based	SS
( ) Sortie	SOR

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CONSTRUCTION/SERVICING COMPLEXITY
( ) Low
(X) Medium
( ) High

Operations Times

OTV Up/Down	0 days
OTV or TMS on Orbit	0 days
Mission Use	180 days/year
IVA Service	20 man-days/year
EVA Service	90 man-days/year
Experiment Ops	90 man-days/year
Service Frequency	10 times/year

Delta Velocities
Up
Down
Aero Return

Support Equipment

Length:	meters	Width:	meters	Height:	meters	(Stowed)
Length:	meters	Width:	meters	Height:	meters	(Deployed)

Mass: kg

Manifest Restrictions
( ) No Restrictions
( ) Only with compatible payloads
( ) Fly-Alone
( ) Must have Docking Module

Length of Beam Fab
Number of Appendages 1
Number of Modules Required to Assemble the Payload 2

Figure 3.3.2-1. BACX 2037 Construction and Storage Facility (LL SS-1) Cont'd

PAYLOAD ELEMENT NAME
ROBOTICS

CODE
BACX2075

CONTACT
Name H.B. LIEMOHN
Address BOEING AEROSPACE

Telephone 206/773-1764

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TYPE
( ) Science and Applications (Non-comm.)
( ) Commercial
(X) Technology Development
( ) Operations
( ) Other
( ) National Security
Type number (see table A) 15

Importance of the Space Station to this Element
1 = Low Value, But Could Use
10 = Vital
Scale = 7

STATUS
( ) Operational ( ) Approved ( ) Planned (X) Candidate ( ) Opportunity

Desired First Flight, Year: 1996 Number of Flights 1 Duration of Flight, Days 180

OBJECTIVE
ROBOTICS TECHNOLOGY DEMONSTRATION: SITUATION MONITORING, ARTIFICIAL INTELLIGENCE, SOFTWARE DEVELOPMENT, MOBILITY CONTROL, END-EFFECTORS, PROPULSION SYSTEMS, AND STRUCTURES AND MATERIALS.

DESCRIPTION
DEVELOP ROBOTS, TO ACCOMPLISH ASSEMBLY AND MAINTENANCE TASKS. UTILIZE THESE ROBOTS TO ACCOMPLISH SPECIFIC TASKS AND DEMONSTRATE THE CAPABILITIES LISTED IN THE OBJECTIVE.

ORBIT CHARACTERISTICS
Geosynchronous Orbit ( ) Yes ( ) No
Apogee, km Perigee, km
Inclination, deg Tolerance + -
Nodal Angle, deg Tolerance + -
Escape dV Required, m/s Ephemeris Accuracy, m

POINTING/ORIENTATION
View Direction ( ) Inertial ( ) Solar ( ) Earth ( ) Any
Truth Sites (if known):
Pointing Accuracy, arc-sec Field of View (deg)
Pointing Stability (Jitter), arc-sec/sec
Special Restrictions (Avoidance)

POWER
( ) AC ( ) DC

	Power, W	Duration, Hrs/Day
Operating	3000	
Standby		
Peak		

( ) Continuous
Voltage, V Frequency, Hz

DATA/COMMUNICATIONS
Monitoring Requirements:
( ) None (X) Realtime ( ) Offline ( ) Other:
( ) Encription/Decription Required
( ) Uplink Required: Command Rate (KBS): Frequency (MHz):
( ) On-Board Data Processing Required
Description:
Data Types: ( ) Analog ( ) Digital Hours/Day
Film (Amount): Voice (Hours/Day):
Live TV (Hours/Day): 8.00 Other:
On-Board Storage (Mbit):
Data Dump Frequency (Per Orbit) Downlink command rate:
Recording Rate (KBPS) Downlink Frequency (MHz):

THERMAL
(X) Active ( ) Passive
Temperature, deg C Operational Minimum Maximum
Non-operational Minimum Maximum
Heat Rejection, W Operational Minimum Maximum
Non-operational Minimum Maximum

EQUIPMENT PHYSICAL CHARACTERISTICS
Location ( ) Internal (X) External ( ) Remote
Equipment ID/Function ( ) Pressurized (X) Unpressurized
Length: 1.78 meters Width: 1.27 meters Height: 1.1 meters (Stowed)
Length: 7.90 meters Width: 1.27 meters Height: 1.1 meters (Deployed)
Launch mass, kg: 3629 Return mass, kg:
Consumable Types
Acceleration Sensitivity, (g) min: max:

CREW REQUIREMENTS
Crew Size 5

Skills (See Table B)

Task Assignments

Skill	5	8	9	12	13					
Level	3	2	2	3	3					
Hours/Day	8.00	4.00	4.00	8.00	8.00					

EVA (X) Yes ( ) No Reason SETUP & ADJUSTMENT Hours/EVA 540

SERVICING/MAINTENANCE
Service: Interval days Consumables kg
Returnables kg Man hours required
Configuration Changes: Interval days Man-Hours Required
Deliverables kg Returnables kg

SPECIAL CONSIDERATIONS/See instructions

Figure 3.3.2-3: BACX 2075 Robotics

Boeing-Specific Input Data	
MISSION TYPE	OPS CODE
Free Flyer	
( ) Not Serviced	F
( ) Remote TMS	FT
( ) Remote Manned	FM
( ) Serviced at Station (TMS Retrieved)	FST
( ) Serviced at Station (Self-propelled)	FS
Platform Based	
( ) Not Serviced	P
( ) Remote TMS	PT
( ) Remote Manned	PM
( ) Serviced at Station (TMS Retrieved)	PST
( ) Serviced at Station (Self-propelled)	PS
Other	
(X) Space Station Based	SS
( ) Sortie	SOR

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CONSTRUCTION/SERVICING COMPLEXITY
(X) Low
( ) Medium
( ) High

Operations Times	
OTV Up/Down	0 days
OTV or TMS on Orbit	0 days
Mission Use	365 days/year
IVA Service	10 man-days/year
EVA Service	20 man-days/year
Experiment Ops	20 man-days/year
Service Frequency	4 times/year

Delta Velocities	
Up	0.00
Down	0.00
Aero Return	0.00

Support Equipment

Length:	1.00 meters	Width:	.50 meters	Height:	.50 meters	(Stowed)
Length:	3.00 meters	Width:	1.00 meters	Height:	1.00 meters	(Deployed)
Mass:	100 kg					

Manifest Restrictions
(X) No Restrictions
( ) Only with compatible payloads
( ) Fly-Alone
( ) Must have Docking Module

Length of Beam Fab	0.00
Number of Appendages	120
Number of Modules Required to Assemble the Payload	2

Figure 3.3.2-3. BACX 2075 Robotics Cont'd

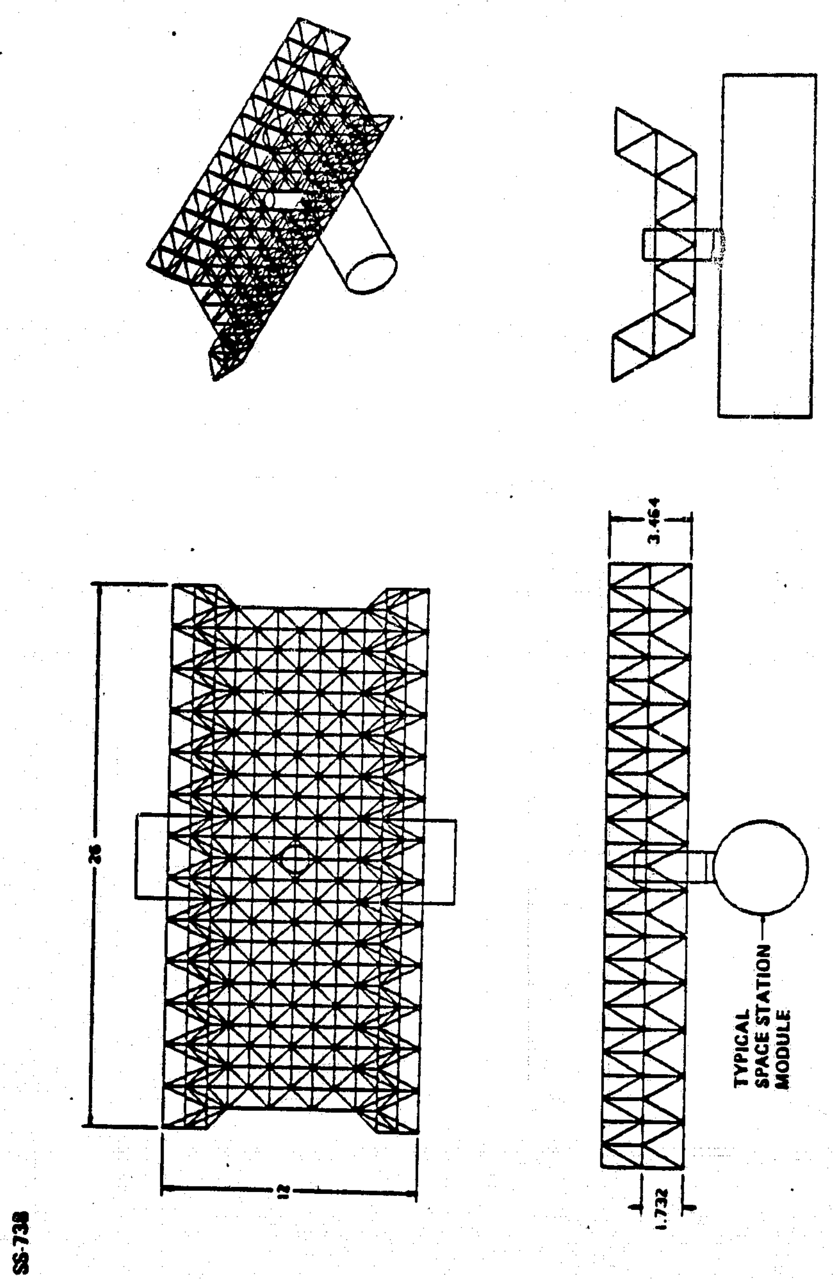

Figure 3.3.2-2. Construction/Storage Facility

With the diversity of inputs, it was obvious that in identifying technology development missions each expert included a wide range of missions in his list and this created an overlap and duplication of some missions.

In order to provide an organized and uniform means of sorting these missions, all candidate missions were screened as to:

1. Is it a reasonable mission?
2. Does it duplicate or overlap others?
3. Does it need to be conducted on the space station?
4. Can it be accommodated by a space station?

The results of this screening process can be seen in Table 3.3.3-2. Missions that were in the science and applications or commercial category were identified and that category's appropriate mission cross reference number was noted. Missions that duplicated or overlaped each other were combined and the resulting technology development mission that accomplished that mission's objective was noted. Missions that didn't need to be accomplished on the space station or didn't have any discernable rationale or purpose were deleted. When the screening of the identified technology development missions was completed they were reviewed by the members of the science and applications, and commercial mission areas to insure all missions were correctly categorized and cross referenced.

After screening the candidate missions, a list of thirty-seven valid technology development missions was developed. These missions are shown in Table 3.3.3-2. A summary report was generated of the computer data base and a copy of the computer tape was forwarded to NASA.

The Technology Development Missions -

Crew Systems - Emesis Station,
Dishwasher/Clothes Washer,
Manipulator Develop & Test Facil.,

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Table 3.3.3-2. Valid Technology Development Missions

BACX2001	PASSIVE MW RADIOM (LSS-3)
BACX2008	LARGE SOLAR COLL (LSS-6)
BACX2009	SPACE COMPONENT LIFETIME TECH.
BACX2011	LIQUID DROPLET RADIATOR
BACX2012	ION THRUSTER EFFECT ON LEO POWER
BACX2013	CREW SYSTEMS—EMESIS STATION
BACX2014	DISHWASHER/CLOTHES WASHER
BACX2018	FIRE SAFETY TECHNOLOGY
BACX2019	TETHER DYNAMICS TECHNOLOGY
BACX2020	LARGE SPACE POWER SYSTEM TECH.
BACX2023	SOLAR SUSTAINED PLASMAS
BACX2026	MULTI-FREQ. HIGH GAIN ANTENNA
BACX2027	SINGLE CRYSTAL RHODIUM WAFERS
BACX2029	HABITABILITY CRITERIA VALIDATION
BACX2034	SPACECRAFT HANGAR (LSS-2)
BACX2035	MATERIALS EXPOSURE LAB
BACX2036	PRECISION OPTICAL SYSTEM (LSS-4)
BACX2037	CONST. AND STORAGE FAC (LSS-1)
BACX2056	SOLAR PUMPED LASERS
BACX2059	MANIPULATOR DEVELOP. AND TEST FACILITY
BACX2060	SHOWER STATION
BACX2061	TRASH MANAGEMENT
BACX2063	PROP. TRANSFER TECH DEMO (OTV-1)
BACX2064	PROP. STORAGE TECH. DEMO (OTV-2)
BACX2065	RNDZVX, DCKG, BRTHE TECH. DEMO (OTV)
BACX2066	OTV MAINT. TECH. DEMO. (OTV-4)
BACX2067	PAYLOAD/OTV INTEG. TECH. DEMO. (OTV)
BACX2068	CLOSED ECLS FOR SPACE STATION
BACX2069	SOLAR ARRAY ADDITION TECH DEMO
BACX2070	FORMATION FLYING TECH. DEMO. (SS-2)
BACX2071	SATELLITE ASSY. TECH. DEMO. (SS-3)
BACX2072	ON-BOARD SAT. SERV. TECH. DEMO. (SS-4)
BACX2073	INSITU SAT UNMANNED SERV TECH DEMO (SS-5)
BACX2074	SURFACE INTERACTION W/RCS PLUME
BACX2075	ROBOTICS

Shower Station,
Trash Management, and
Closed ECLS for Space Station

are being developed as part of the Space Station architecture and are only included in the technology development valid mission list to insure adequate attention to their design and testing. In addition, operational testing and experience will be utilized to improve the design for the evolutionary growth configurations. These and other space station hardware development missions should be reexamined to make them consistant with the to-be-determined space station technology development plans to be definedin summer 1983.

3.3.4 Costs

To determine the rough order of magnitude costs for the Technology Development Missions, a second screen was run. This screen was to evaluate the payload costs and determine the priority of the missions. The intent of this evaluation is to develop a fiscally constrained time-phased presentation of Technology Development Missions.

The mission data forms plus all pertinent additional study and design information was utilized to prepare a cost analysis data worksheet. The Boeing cost modeling and operations analysis group then processed this data using either the RCA PRICE hardware, or the Boeing PCM hardware computer costing models. Several missions will use off-the-shelf hardware and these were priced using data from like programs or by data from experts in the field. The resulting cost summary Table 3.3.4-1 gives the Rough Order of Magnitude (ROM) costs for the Technology Development Missions.

As a result of the cost analysis, it was determined that the thirty-seven missions remaining after the reasonableness screen represented a greater demand for development funds than would be available in the 1900 to 2005 time frame. Therefore, the missions were evaluated using payload costs and priority to determine which missions were to be deleted. As the result of this cost analysis and priority screen, four more Technology Development Missions were deleted. They are BACX2008, Large Solar Collector (LSS-6), BACX2023, Solar-Sustained Plasmas, BACX2026, Multi-Freq. High Gain Antenna, and BACX2056, Solar Pumped Lasers.

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Table 3.3.4-1. Technology Development Mission Cost Summary (Millions)

		ENGR COSTS	PROTO COSTS	FLIGHT UNIT COSTS	TOTAL COST
BACX2001	PASSIVE MW RADIOM (LSS-3)	47.1	24.7	12.3	84.1
BACX2008	LARGE SOLAR COLL (LSS-6)	21.7	24.6	12.3	58.6
BACX2009	SPACE COMPONENT LIFETIME TECH.	3.1	2.7	1.3	7.1
BACX2011	LIQUID DROPLET RADIATOR	34.1	21.2	10.7	66.1
BACX2012	ION THRUSTER EFFECT ON LEO POWER	2.6	1.3	3.9	4.6
BACX2013	CREW SYSTEMS–EMESIS STATION				2
BACX2014	DISHWASHER/CLOTHES WASHER	1.3	.4	.2	1.9
BACX2018	FIRE SAFETY TECHNOLOGY	3.6	3.4	1.7	8.7
BACX2019	TETHER DYNAMICS TECHNOLOGY				11.8
BACX2020	LARGE SPACE POWER SYSTEM TECH.	25.4	35.4	17.7	78.5
BACX2023	SOLAR-SUSTAINED PLASMAS	2.7	1.9	0.9	5.5
BACX2024	LOW COST MODULAR SOLAR PANEL TECH.	.8	.6	.3	1.7
BACX2026	MULTI-FREQ. HIGH GAIN ANTENNA				66
BACX2027	SINGLE CRYSTAL RHODIUM WAFERS	1.6	.3	.15	2
BACX2029	HABITABILITY CRITERIA VALIDATION	.9	.18	.09	1.2
BACX2034	SPACECRAFT HANGAR (LSS-2)	4.6	1.0	1.0	6.6
BACX2035	MATERIALS EXPOSURE LAB	1.6	.7	.4	2.7
BACX2036	PRECISION OPTICAL SYSTEM (LSS-4)	40.7	26.9	13.5	81.1
BACX2037	CONST. AND STORAGE FAC. (LSS-1)	43.8	8.7	8.8	51.3
BACX2056	SOLAR PUMPED LASERS	.7	1.3	.6	2.6
BACX2059	MANIPULATOR DEVELOP AND TEST FACILITY				100
BACX2060	SHOWER STATION	3.6	.28	1.4	4
BACX2061	TRASH MANAGEMENT	1.5	.2	1.8	.1
BACX2063	PROP. TRANSFER TECH. DEMO. (OTV-1)	15.1	5.3	5.3	25.7
BACX2064	PROP STORAGE TECH. DEMO. (OTV-2)				0
BACX2065	RNDZVX, DCKG, BRTHE TECH. DEMO (OTV)				0
BACX2066	OTV MAINT. TECH. DEMO. (OTV-4)				29.5
BACX2067	PAYLOAD/OTV INTEG. TECH. DEMO. (OTV)				0
BACX2068	CLOSED ECLS FOR SPACE STATION	46	4.2	4.2	51
BACX2069	SOLAR ARRAY ADDITION TECH. DEMO.				0
BACX2070	FORMATION FLYING TECH. DEMO. (SS-2)				0
BACX2071	SATELLITE ASSY. TECH. DEMO. (SS-3)				24.5
BACX2072	ON-BOARD SAT. SERV. TECH. DEMO. (SS-4)				0
BACX2073	INSITU SAT UNMANNED SERV TECH DEMO (SS-5)				0
BACX2074	SURFACE INTERACTION W/RCS PLUME	.2	.5	.2	.9
BACX2076	ROBOTICS	56	15	7.5	78

In figuring these payload costs, the crew systems-emesis station, dishwasher/clothes washer, shower station, trash managment, closed ECLSS for space station, and part of the manipulator development and test facility technology development missions were assigned to the space station development and not considered in the technology development missions budget line.

3.3.5 Mission Scheduling

The scheduling rationale developed in the 1971 Space Station studies was used as a starting point. We continued this effort to categorize experiments for scheduling, then conducted analysis of feasible experiment combinations. To arrive at a comprehensive Technology Development schedule a budget level was established and a preliminary ordering of experiments was accomplished.

This scheduling was an iterative process to arrive at a satisfactory blend of demands on the space station system versus meeting the experimenter's appetites and our imposed budget constraints. The resulting technology development mission schedule and budget, as shown in Table 3.3.5-1, was then integrated into the overall mission model.

In developing this technology development mission schedule, the following capabilities and limitations were considered.

- o Facilities, subsystems, crew and resources available at each plateau were evaluated to determine level of experiments that can be accomplished.
- o Experiment schedule wa evolved based on station capability, experiment categories, commonality of equipment and cost of equipment.
- o Scheduling Criteria.
    - o High benefit experiments early in program.
    - o Precursor experiments must be accomplished early in program.
    - o Experiments that utilize common equipment or personnel should be scheduled together or in sequence.
    - o Resource availability.

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Table 3.3.5-1. Technology Development Schedule and Budget

	MISSIONS	FLIGHT DATE	DURATION (MONTHS)	COST IN MILLIONS	FUNDING SOURCE
BACX2037	CONST AND STORAGE FAC (LSS-1)	91	12	61.3	TD
BACX2034	SPACECRAFT HANGAR (LSS-2)	91	12	6.6	TD
BACX2059	MANIPULATOR DEVELOP AND TEST FACILITY	91	24	100	SS
BACX2013	CREW SYSTEMS—EMESIS STATION	91	12	29	SS
BACX2014	DISHWASHER/CLOTHES WASHER	91	12	1.9	SS
BACX2060	SHOWER STATION	91	12	4	SS
BACX2061	TRASH MANAGEMENT	91	12	1.8	SS
BACX2068	CLOSED ECLS FOR SPACE STATION	91	12	51	SS
BACX2063	PROP TRANSFER TECH DEMO (OTV-1)	92	6	25.7	TD
BACX2064	PROP STORAGE TECH DEMO (OTV-2)	92	6	0	TD
BACX2069	SOLAR ARRAY ADDITION TECH DEMO	92	1	0	TD
BACX2066	OTV MAINT TECH DEMO (OTV-4)	93	24	29.5	TD
BACX2065	RNDZVX, DCKG, BRTHE TECH DEMO (OTV)	93	1	0	TD
BACX2071	SATELLITE ASSY TECH DEMO (SS-3)	94	36	25	TD
BACX2067	PAYLOAD/OTV INTEG TECH DEMO (OTV)	94	1	0	TD
BACX2070	FORMATION FLYING TECH DEMO (SS-2)	94	1	0	TD
BACX2072	ON-BOARD SAT SERV TECH DEMO (SS-4)	94	1	0	TD
BACX2018	FIRE SAFETY TECHNOLOGY	95	3	8.7	TD
BACX2020	LARGE SPACE POWER SYSTEM TECH	95	3	10	TD
BACX2029	HABITABILITY CRITERIA VALIDATION	95	12	1.2	TD
BACX2024	LOW COST MODULAR SOLAR PANEL TECH	95	3	1.7	TD
BACX2009	SPACE COMPONENT LIFETIME TECH	96	24	7.1	TD
BACX2027	SINGLE CRYSTAL RHODIUM WAFERS	96	3	2	TD
BACX2075	ROBOTICS	97	6	78	TD
BACX2073	INSITU SAT UNMANNED SERV TECH DEMO (SS-5)	97	1	0	TD
BACX2012	ION THRUSTER EFFECT ON LEO POWER	98	3	4.6	TD
BACX2035	MATERIALS EXPOSURE LAB	98	12	2.7	TD
BACX2036	PRECISION OPTICAL SYSTEM (LSS-4)	00	12	81.1	TD
BACX2074	SURFACE INTERACTION W/RCS PLUME	01	3	.9	TD
BACX2001	PASSIVE MW RADIOM (LSS-3)	02	12	84.1	TD
BACX2019	TETHER DYNAMICS TECHNOLOGY	03	3		TD
BACX2011	LIQUID DROPLET RADIATOR	06	12	66.1	TD

3.3.6 Laboratory

In conducting this missions analysis, it was determined that many of the experiments could share not only hardware, but interfaces, information and test equipment. Figure 3.3.6-1 shows the interrelationships of the OTV, Satellite, Robotics, Manipulator, and Cryogenic Missions. The large space structures missions will share test equipment with the habitability criteria validation mission.

In analyzing the individual technology development missions, it has become apparent that there is a requirement for a general laboratory facility on the space station. This laboratory should consist of common lab equipment: i.e., work bench, vice, power supplies, storage for tools and equipment, a computer terminal, plotter, printer, sine square wave generator, oscilloscope, multimeter, microscope, furnace, vacuum chamber, soldering capability, and complete set of hand tools.

Technology Development Mission Tasks that would utilize a general laboratory facility:

Assembly - assemble small modules for satellite (BACX 2071, 2072) and OTV missions. (BACX 2066)

Failure Analysis - conduct failure analysis of parts for space component lifetime technology. (BACX 2009) Conduct general diagnosis on faulty equipment.

Maintenance - provide any required scheduled or unscheduled maintenance to keep experiments working.

Equipment Calibration - provide specialized equipment required to calibrate mission equipment, e.g., noise level meter. (BACX 2029).

Liquid Analysis - provide equipment to analyze: results of bromine phase separation (BACX 2006), liquids used or generated by fire safety experiment (BACX 2018), liquids utilized in liquid droplet radiator (BACX 2011), and in the cryogenic fluid management missions. (BACX 2063, 2064).

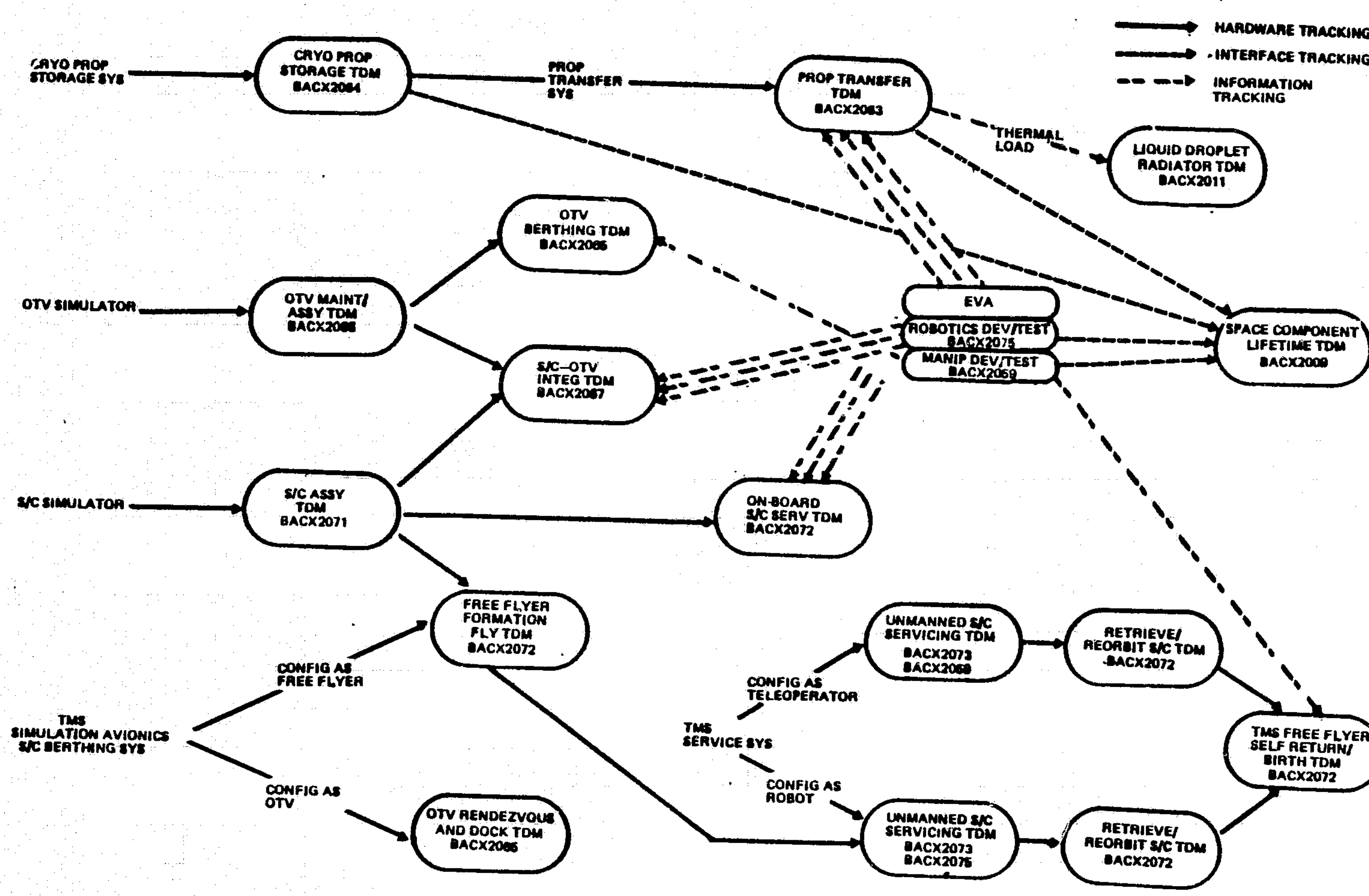

Figure 3.3.6-1. TDM Interrelationships

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Crystal Analysis - provide capability to cut and analyze the rhodium crystals grown in the laboratory furnace. (BACX 2027).

Surface Analysis - analyze surface of materials used in Materials Exposure Mission (BACX 2035) and any other exposed materials brought in for repair or maintenance.

The other mission categories would also make extensive use of the General Purpose laboratory facilities. The laboratory would also provide the capability to reconfigure mission hardware and modify or improve experimental design. In addition, critical space station or mission maintenance tasks could be more adequately accomplished in this lab.

Maintenance effectiveness is a function of task complexity and operator capability. The maintenance task complexity demands that adequately equipped facilities be available for the accomplishment of these tasks.

The ability of the operator to perform maintenance tasks will be enhanced by providing adequate facilities. The general purpose laboratory, that has been proposed, will provide most maintenance support requirements. Capabilities of the General Purpose Laboratory in the maintenance role are:

1) An organized work area with adequate hold downs for tools, equipment parts, and manuals.
2) Restraints to counteract the operator forces required during maintenance tasks.
3) Test equipment (oscilloscope/multimeter, etc) at an optimized work bench.
4) Computer and data handling facilities.
5) Organized storage areas for maintenance spaces and components.

The provision of a general laboratory workshop with standard equipment would enable more tasks to be accomplished without the weight penalty of having to supply general test and evaluation equipment with each and every mission payload.

It has also been noted that several of the mission specialists now in the NASA Program have expressed a need for a general purpose laboratory for use in their off hours activities. These

individuals have expressed a need to conduct independent research on their own time and feel a well-equipped laboratory is a necessity.

Several NASA/JSC memo's prepared by Dr. F. R. Cheng identify requirements for a general purpose laboratory and provide a list of basic laboratory equipment and alternative laboratory locations. He feels that a laboratory will enhance and utilize human resources and capabilities and provide the capability to diagnose, repair, and reconfigure hardware as well as conduct multipurose scientific research.

3.3.7 Architectural Drivers

During the selection and development of the technology development missions close contact was maintained with the Space Station designers. This enabled design to identify and define any unique capabilities or functions that would be required of the Space Station. It was determined that the Technology Development missions are generally independent of specific Space Station configurations. There is, however, a range of space station services required for each mission. These configuration requirements were collated from the mission data forms and other sources and are summarized in Table 3.3.7-1.

These configurations requirements were then used to identify any architecture drivers to be used during preliminary design in the Space Station configuration trade studies. One of these drivers identified in the configuration requirements Table 3.3.7-1 is mission mass. Figure 3.3.7-1 shows that from 1993 to 1995 the OTV technology demonstrations along with the satellite technology demonstrations are going to impact the space station's CG and therefore the RCS. This type of information for each mission was then incorporated in the candidate configurations to provide adequate interface provisions to support the Technology Development mission schedule and requirements.

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Table 3.3.7-1. Technology Development Configuration Requirements

MISSIONS		ORBIT: INCLINATION (DEGREES)	ORBIT: ALTITUDE (KM) – (A) ANY, (L) LOW	PROGRAM: SCHEDULE (YEAR)	PROGRAM: NUMBER OF FLIGHTS	PROGRAM: DURATION (MONTHS)	PROGRAM: UPPER STAGE	SIZE/WEIGHT: VOLUME (M^3)	SIZE/WEIGHT: WEIGHT (KG)	INTERFACE: POWER AV./PEAK (KW)	INTERFACE: HEAT REJECTION MIN/MAX	INTERFACE: ORIENTATION - (I) (S) (E) (A) ANY	INTERFACE: POINTING/STAB ARC SEC/ARC-SEC/SEC	INTERFACE: DATA	INTERFACE: BERTHING PORT	INTERFACE: INTERNAL	INTERFACE: EXTERNAL	INTERFACE: S.S. MANIPULATOR	INTERFACE: PLATFORM (P) HANGAR (H)	OPERATIONS: IVA	OPERATIONS: EVA	OPERATIONS: FREE FLYER SERVICING (S), REMOTE (R)	ENVIRONMENT: LOW CONTAMINATION	ENVIRONMENT: "O" G	ENVIRONMENT: MICRO METEROID PROTECTION	ENVIRONMENT: RADIATION PROTECTION
BACX2037	CONST AND STORAGE FAC (LSS-1)	28.5	A	91	1	12		1092	2000	1		A			X		X	X			X					
BACX2034	SPACECRAFT HANGAR (LSS-2)	28.5	A	91	1	12		1458	270	1		A					X	X	P		X					
BACX2056	MANIPULATOR DEVELOP AND TEST FACILITY	28.5	A	91	1	24		8.25	2500	2	2	A		X	X		X	X			X					
BACX2013	CREW SYSTEMS-EMESIS STATION	28.5	A	91	1	12		.25	100	.2	.2	A				X				X						
BACX2014	DISHWASHER/CLOTHES WASHER	28.5	A	91	1	12		1	100	.5	.5	A				X										
BACX2060	SHOWER STATION	28.5	A	91	1	12		3.4	25	1	1	A				X										
BACX2061	TRASH MANAGEMENT	28.5	A	91	1	12		3.4	40	.5	.5	A				X										
BACX2068	CLOSED ECLS FOR SPACE STATION	28.5	A	91	1	12		6	850	4	4	A		X		X										
BACX2063	PROP TRANSFER TECH DEMO (OTV-1)	28.5	A	92	1	6		121	10000	1	1	A		X			X	X	P	X	X					
BACX2064	PROP STORAGE TECH DEMO (OTV-2)	28.5	A	92	1	6		0	0	1	1	A		X			X		P	X	X				X	
BACX2069	SOLAR ARRAY ADDITION TECH DEMO	28.5	A	92	1	1		0	0			S		X			X	X		X	X					
BACX2066	OTV MAINT TECH DEMO (OTV-4)	28.5	A	93	1	24		284	35834			A					X	X	P/M	X	X					
BACX2065	RNDZVX, DCKG, BRTHE TECH DEMO (OTV)	28.5	A	93	1	1		0	0			A		X	X	X	X	X	P	X	X					
BACX2071	SATELLITE ASSEMBLY TECH DEMO (SS-3)	28.5	A	94	1	36		738	2640			A					X	X	P/M	X	X					
BACX2067	PAYLOAD/OTV INTEG TECH DEMO (OTV)	28.5	A	94	1	1		0	0			A					X	X	P/M	X	X					
BACX2070	FORMATION FLYING TECH DEMO (SS-2)	28.5	A	94	1	1		0	0			A					X	X	P	X	X	X				
BACX2072	ON-BOARD SAT SERV TECH DEMO (SS-4)	28.5	A	94	1	1		0	0			A					X	X	P/M	X	X					
BACX2018	FIRE SAFETY TECHNOLOGY		A	95	1	3		84	250	.5	1	A		X			X		P	X	X					
BACX2029	LARGE SPACE POWER SYSTEM TECH	28.5	A	95	1	3		144	1197			S														
BACX2029	HABITABILITY CRITERIA VALIDATION	28.5	A	95	1	12		.125	5			A		X		X	X			X	X					
BACX2024	LOW COST MODULAR SOLAR PANEL TECH	28.5	A	95	1	3		.04	9			S		X			X	X			X		X			

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Table 3.3.7-1. Technology Development Configuration Requirements - Continued

MISSIONS	ORBIT: INCLINATION (DEGREES)	ORBIT: ALTITUDE (KM) – (A) ANY, (L) LOW	PROGRAM: SCHEDULE (YEAR)	PROGRAM: NUMBER OF FLIGHTS	PROGRAM: DURATION (MONTHS)	PROGRAM: UPPER STAGE	SIZE/WEIGHT: VOLUME (M^3)	SIZE/WEIGHT: WEIGHT (KG)	INTERFACE: POWER AV./PEAK (KW)	INTERFACE: HEAT REJECTION MIN/MAX	INTERFACE: ORIENTATION - (I) (S) (E) (A) ANY	INTERFACE: POINTING/STAB ARC SEC/ARC-SEC/SEC	INTERFACE: DATA	INTERFACE: BERTHING PORT	INTERFACE: INTERNAL	INTERFACE: EXTERNAL	INTERFACE: S.S. MANIPULATOR	INTERFACE: PLATFORM (P) HANGAR (H)	OPERATIONS: IVA	OPERATIONS: EVA	OPERATIONS: FREE FLYER SERVICING (S), REMOTE (R)	ENVIRONMENT: LOW CONTAMINATION	ENVIRONMENT: "0" G	ENVIRONMENT: MICRO METEROID PROTECTION	ENVIRONMENT: RADIATION PROTECTION
BACX2009 SPACE COMPONENT LIFETIME TECH	28.5	A	96	1	24		.125	45	.1	.1	A		X		X	X			X	X					
BACX2027 SINGLE CRYSTAL RHODIUM WAFERS	28.5	A	96	1	3		1	200	1	1	A		X		X				X				X		
BACX2075 ROBOTICS	28.5	A	97	1	6		11	3629	3	3	A		X			X	X	P/M	X	X					
BACX2073 INSITU SAT UNMANNED SERV TECH DEMO (SS-5)	28.5	A	97	1	1		0	0			A		X		X	X	X	P	X	X	X				
BACX2012 ION THRUSTER EFFECT ON LEO POWER	28.5	A	98	1	3		1	112			A		X			X				X		X			
BACX2035 MATERIALS EXPOSURE LAB	28.5	A	98	1	12		.1	202	.1	.1	A				X	X	X		X	X					
BACX2036 PRECISION OPTICAL SYSTEM (LSS-4)	28.5	A	00	1	12		4032	1296			I		X			X	X	P	X	X	X	X			
BACX2074 SURFACE INTERACTION W/RCS PLUME	28.5	A	01	1	3		.7	100								X				X					
BACX2001 PASSIVE MW RADIOM (LSS-3)	28.5	A	02	1	12		865K	2000			I		X			X	X	P	X	X	X				
BACX2019 TETHER DYNAMICS TECHNOLOGY	28.5	A	03	1	3		19	705	.2		E		X			X	X	P		X					
BACX2011 LIQUID DROPLET RADIATOR	28.5	A	05	1	12		75	3600	.5		I		X			X	X	P	X	X					

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LOW INCLINATION SPACE STATION

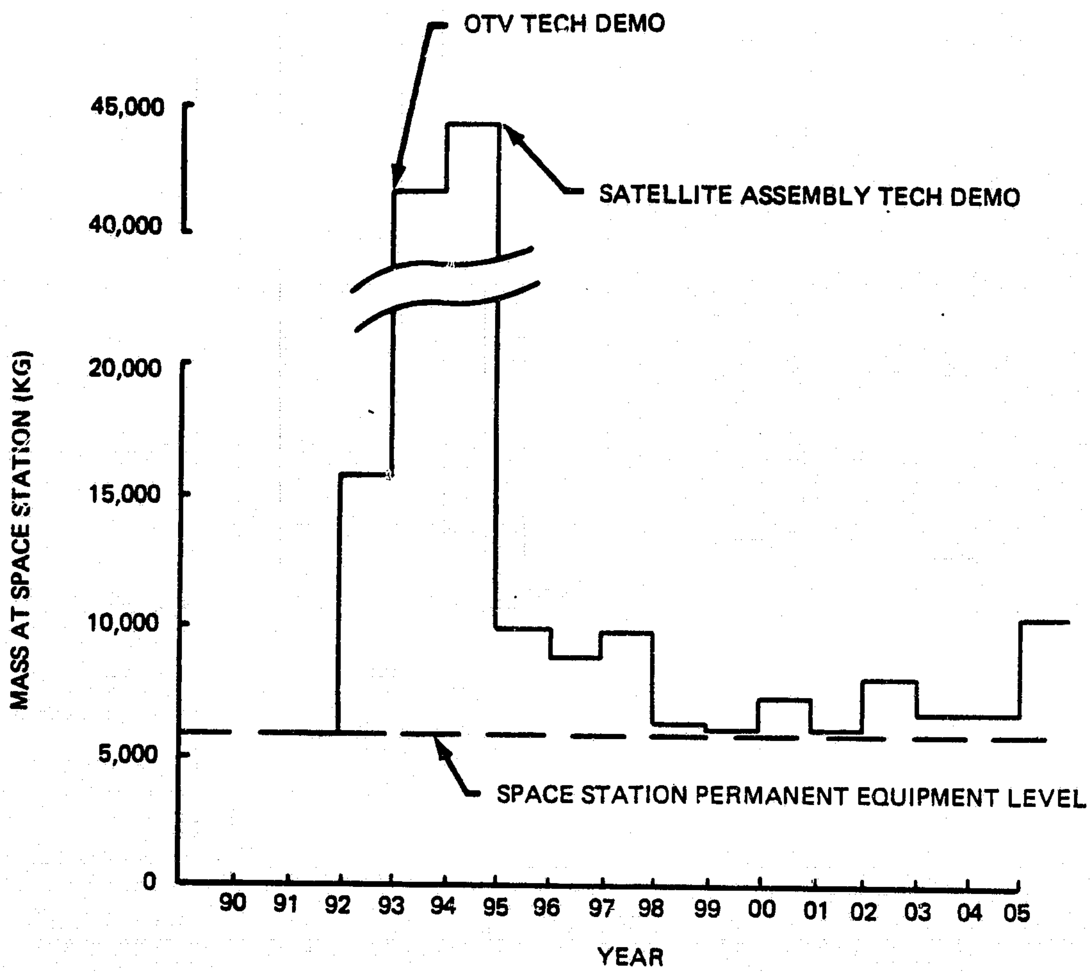

Figure 3.2.3-2. Technology Development Missions Mass at Space Station

3.4 SPACE OPERATIONS MISSIONS

3.4.1 Introduction

There are three types of missions that have become to be known as "space operations missions". These are missions that involve 1) space construction, 2) flight support and/or 3) servicing. The specific payloads defined for other mission types (i.e., science and applications, commercial, technology development, and national security missions) will sometimes require one or more of these "space operations" to be provided to implement the mission. Table 3.4-1 specifies the logical combinations of space operations that may be required for some example payload types.

In the following subsections, the space operations are defined, the payloads requiring the various space operations will be identified and the space station accommodation requirements will be listed.

3.4.2 Space Construction Operations

3.4.2.1 Introduction

Space construction operations include deployment of appendages, assembly of modules, fabrication of structure, installation of subsystems, and test and checkout of spacecraft.

3.4.2.2 Missions Requiring Construction Operations

The missions which will require construction operations and the nature of construction operations required are summarized in Table 3.4-2. (Note—These missions and their time-phasing are from the "mission driven scenario," see Sec. 4.2.1 and 5.2.) The source of the identification of the construction missions was the data provided by the mission analysts on the mission data forms. Figure 3.4-1 shows the time-phasing of these missions.

3.4.2.3 Space Construction Operations Accommodation Requirements

Figure 3.4-2 lists the time-phased construction support accommodations required at the Space Station.

Table 3.4-1 Space Operations That Will Be Required For Example Payloads

EXAMPLE PAYLOAD	SPACE OPERATIONS REQUIRED Construction	Flight Support	Servicing
Life Sciences Payload On-Board Space Station	(No Space Operations Involved) Using our definitions		
Small GEO Satellite (e.g., weather satellite)		X	
Small LEO Satellite Initially Placed In Orbit by Orbiter			X
Co-orbiting Unmanned Platform	X	X	X
Co-orbiting Materials Processing Free-Flyer Spacecraft		X	X

Note: This table shows the only logical combinations of space operations.

Table 3.4-2 Construction Operations Required by the Various Payloads

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NO.	KEY	PAYLOAD DESCRIPTION	DEPLOY APPENDAGES	ASSEMBLE MODULES	INSTALL SUBSYSTEMS	FABRICATE STRUCTURE	TEST & CHECKOUT
			CONSTRUCTION OPERATIONS REQUIRED				
1	S001	EARTH OBSERV. PALLET	●	●			●
2	S002	SYNTH APERTURE RADAR	●	●			●
4	S004	UPPER ATMOS RESEARCH PKG	●	●			●
8	SP02	SPACE PHYSICS PALLET	●	●			●
9	SA01	VLBI/COSMIC RAY PKG	●	●			●
15	SL06	CENTRIFUGE (ADD TO LSRF)			●		●
26	CC03	INTELSAT-7,7A CLASS COMSAT	●	●			●
27	0004	MULTIBEAM COMM. SATELLITE	●	●	●		●
28	0005	RECONFIGURABLE COMM. SATELLITE	●	●	●		●
36	T-C1	CONSTR. STORAGE, & HANGAR		●	●		●
40	T-C1	LARGE POWER SYS TECHNOLOGY	●	●	●		●
42	T-C2	PRECISION OPT CONSTR & TEST	●	●	●		●
43	TM03	PASSIVE MICW RADIOMETER	●	●	●		●
44	TEC2	LIQ DROPLET RADIATOR					●
46	SAC5	LARGE RADIO TELESCOPE	●	●	●	●	●

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CONSTRUCTION TRAFFIC MODEL
TRAFFIC MODEL YEAR

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
1	S001	EARTH OBSERV. PALLET	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	S002	SYNTH APERTURE RADAR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
4	S004	UPPER ATMOS RESEARCH PKG	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
8	SP02	SPACE PHYSICS APLLET	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
9	SA01	VLBI/COSMIC RAY PKG	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	SL06	CENTRIFUGE (ADD TO LSRF)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	CC03	INTELSAT-7,7A CLASS COMSAT	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2
27	0004	MULTIBEAM COMM. SATELLITE	0	0	0	0	0	1	1	1	1	0	0	1	1	0	1	1
28	0005	RECONFIGURABLE COMM. SATELLITE	0	1	1	1	1	2	3	4	4	4	4	4	4	4	4	4
36	T-C1	CONSTR. STORAGE, & HANGAR	0	1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
40	T-C1	LARGE POWER SYS TECHNOLOGY	0	0	0	0	0	1	-1	0	0	0	0	0	0	0	0	0
42	T-C2	PRECISION OPT CONSTR & TEST		0	0	0	0	0	0	0	0	1	-1	0	0	0	0	0
43	TM03	PASSIVE MICW RADIOMETER	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	0	0
44	TEC2	LIQ DROPLET RADIATOR	0	0	0	0	0	0	0		0	0	0	0	0	0	0	1
46	SAC5	LARGE RADIO TELESCOPE	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Figure 3.4-1. Construction Mission Model

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Table 3.4-2. Space Construction Operations Mission Accommodation Requirements

RESOURCES	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
FACILITIES																
TRACK/TRACK SWITCHES/CONTROL						—	—	—	—	—	—	—	—	—	—	—
STORAGE RACK		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
STORAGE FACILITY		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
COMMAND CENTER CONTROLS/DISPLAY		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
GENERAL PURPOSE SUPPORT EQUIPMENT																
MOBILE CHERRYPICKER/HANDLING TOOLS						—	—	—	—	—	—	—	—	—	—	—
PORTABLE EVA WORKSTATION		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EVA SUITS		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EVA HANDTOOLS		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MANIPULATOR		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CONSTRUCTION EQUIPMENT																
CONSTRUCTION FIXTURE		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MODULAR CONSTRUCTION FIXTURE						—	—	—	—	—	—	—	—	—	—	—
TURN/TABLE/TILTABLE		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CONSTRUCTION UMBILICAL SYSTEM/CONTROLS		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
BEAMBUILDER/ATTACHMENTS/CONTROLS										—	—	—	—	—	—	—
CREW SKILLS																
SPACECRAFT SYSTEMS OP–DATA		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SPACECRAFT SYSTEMS OP–ELEC		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SPACECRAFT SYSTEMS OP–MECH		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SPACECRAFT SYSTEMS OP–FLUIDS		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SPACE STATION SYSTEMS OPER		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EVA CHERRYPICKER OPER		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EVA WORKER		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

3.4.3 Flight Support Operations Missions

3.4.3.1 Introduction

Flight support operations are defined to be those operations associated with handling orbital transfer vehicles (OTV's), teleoperator maneuvering systems (TMS's), and the shuttle orbiter that occur at the space station. Figure 3.4-3 is a flow chart that describes the scope of flight support operations.

3.4.3.2 Missions Requiring Flight Support Operations

Table 3.4-3 lists the payloads and the flight support operations required. The source of the flight support operations requirements were the mission data forms. Refer to the flight manifest in Section 4.2 for the time phasing of these payloads.

3.4.3.3 Flight Support Operations Accommodations Requirements

Table 3.4-4 lists the facility, support equipment, and modules that are required to support the various types of vehicles. Figure 3.4-4 shows the time-phased flight support operations accommodations requirements at the space stations. (Note—The time-phasing of these requirements are keyed to the "mission driven scenario," see Sec. 4.2.1 and 5.2.)

3.4.4 Servicing Operations Missions

3.4.4.1 Introduction

Servicing operations are defined to include the following:

On-Board The Space Station

- Space Station maintenance
  (space station housekeeping operations, e.g., resupply, orbit trimming, subsystem operations, etc., are <u>not</u> included in this definition of servicing operations)
- Attached mission equipment maintenance
  (operation of the mission equipment is classified as "experiment operations")

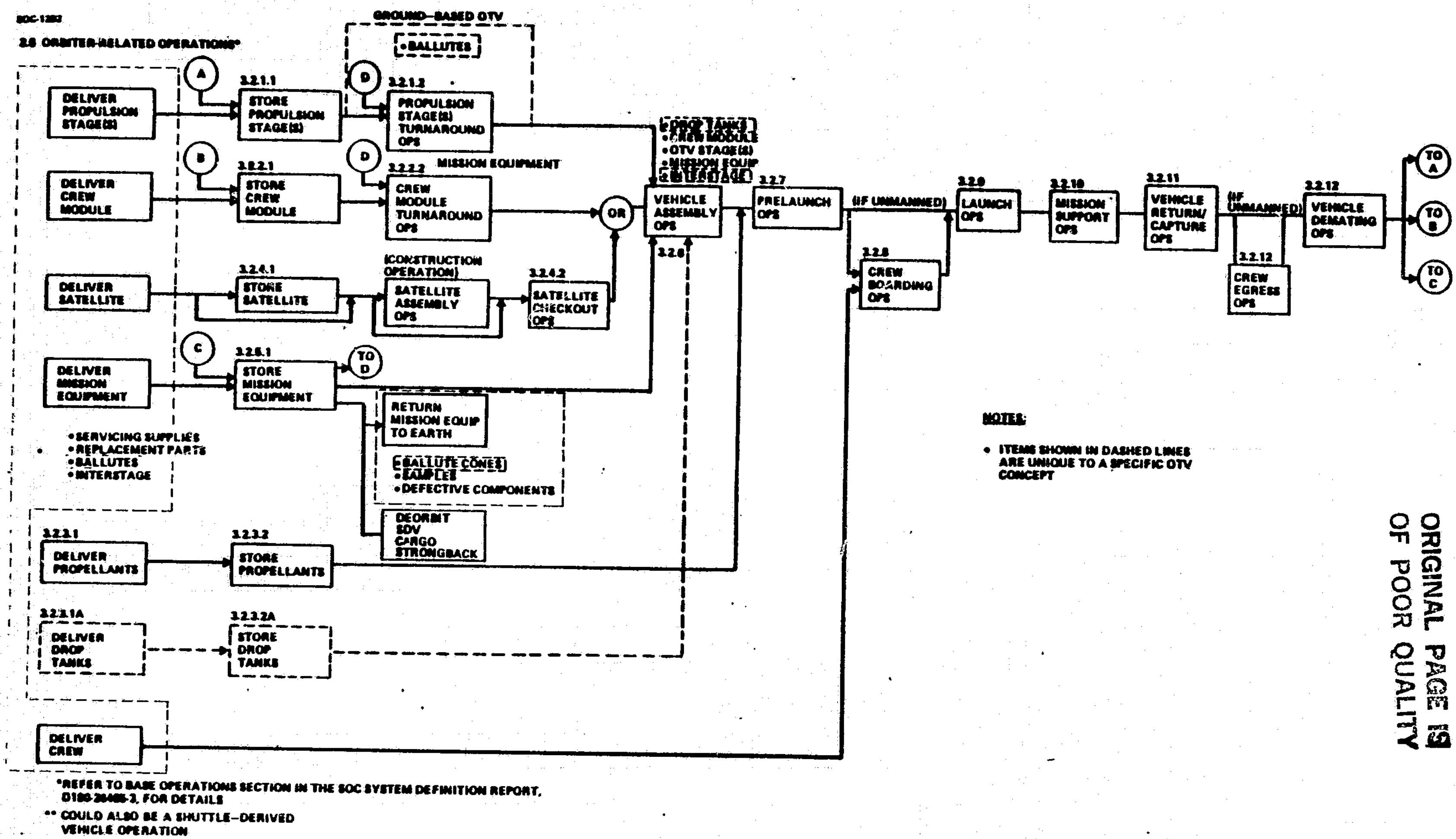

Figure 3.4-3. Flight Support Operations Functional Plan

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Table 3.4-3. Missions Requiring Flight Support Operation

NO.	CODE	NAME	OPS CODE	ORBITER DELIVERY	TMS UNMANNED	TMS MANNED	OTV UNMANNED	OTV MANNED
1	S001	EARTH OBSERV PALLET	SPCL	●				
2	S002	SYNTH APERTURE RADAR	SPCL	●				
3	S003	METERODYNING CO_2 LIDAR	SPXX	●				
4	S004	UPPER ATMOS RESEARCH PKG	SPCL	●				
5	CTC3	SPACE STATION MODULES	SSSS	●				
6	CTC4	HI-INCL STATION RESUPPLY	SCPS	●				
7	SPC1	SPACE SCIENCE SUBSATELLITE	P3XX	●				
8	SPC2	SPACE PHYSICS PALLET	SPCM	●				
9	SAC1	VLBI/COSMIC RAY PKG	SPCL	●				
10	SLC8	RAD BIOLOGY IN SM MAMMALS	SSSA	●				
11	SLC1	HUMAN LIFE SI CARRY-ONS	SSSA	●				
12	SL02	SMALL MAMMALS CARRY-ONS	SSSA	●				
13	SLC3	PLANT DEVEL CARRY-ONS	SSSA	●				
14	SLC4	LIFESCIENCES RES FAC	SPXX	●				
15	SLC5	CENTRIFUGE (ADD TO LSRF)	SSCL	●				
16	SLC6	CLOSED ENV LSS EXPT MOD	SPCL	●				
17	CMC1	MATLS SCIENCE LAB	SPXX	●				
18	CM02	CRYSTAL GROWTH FACTORY/ PLAT	PMCL	●				
19	CM03	CRYSTAL GROWTH RESUP-1	PMXX	●		●		
20	CMC4	CRYSTAL GROWTH RESUP-2	PMCL	●		●		
21	SAC2	ASTRO TELESCOPE CLLSTER	SPXX	●				
22	SAC3	ASTROPHYSICS	FMXM	●		●		
23	SA04	ASTROPHYSICS OBSERVATORIES	FMXM	●		●		
24	CCC1	SUSS-CLASS COMSAT	FXXX	●				
25	CCC2	INTELSAT-6A CLASS COMSAT	FXXX	●			●	
26	CCC3	INTELSAT-7,7A CLASS COMSAT	FXCL	●			●	
27	CCC4	MULTIBEAM COMM. SATELLITE	SSCM	●			●	
28	CCC5	RECONFIGURABLE COMM. SATELLITE	FXCX	●			●	
29	CMC5	CONT FLOW ELECTROPH PLATFORM	PMCL	●				
30	CMC6	CONTINUOUS FLOW ELECTRO RESUPPLY	PMXL	●	●			
31	CM07	GLASS PROC PLANT	SPCL	●				
32	CMC8	GLASS PROC OPTICAL FIBERS	SPCL	●				
33	OT01	LOW INCL STA MODULE DEL	SSSS	●				
34	OT02	LOW INCL STA RESUPPLY	SORS	●				
35	OT05	HI ACT STA RESUPPLY	SORX	●				●
36	TMC1	CONSTR. STORAGE & HANGAR	SPCM	●				
37	TPC1	PROP TRANSFER & STORAGE	SPCL	●				
38	TP02	OTV MAINT TECH DEMOS	SSCL	●	●			
39	TSC1	SATELLITE ASSY & SERVICE	SSCL	●	●			
40	TE01	LARGE POWER SYS TECHN	SSCL	●	●			
41	TC01	ROBOTICS TECH DEMO	SSCM	●				
42	TMC2	PRECISION OPT CONSTR & TEST	SPCH	●				
43	TMC3	PASSIVE MICW RADIOMETER	SPCM	●				
44	TEC2	LIQ DROPLET RADIATOR	SPCL	●				
45	TSC1	TECH DEVEL CARRY-ONS	SSSA	●				
46	SA05	LARGE RADIO	FMCH	●		●		

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Table 3.4-4 *Flight Support Facility, Support Equipment and Modules Applicable to the Various Space Vehicles*

VEHICLE \ FACILITIES/MODULES/ SUPPORT EQUIP. REQ'D		SERVICE MODULE DOCKING PORTS	DOCKING TUNNEL DOCKING PORTS	HANGAR – NO MAINT PROVISIONS	HANGAR – MAINT PROVISIONS	TRACK NETWORK – INITIAL SPACE STATION	TRACK NETWORK – GROWTH SPACE STA CONFIGURATION	TRACK NETWORK – GROWTH SPACE STA CONFIGURATION WITH ADDITIONS	TRACK NETWORK – GROWTH SOC CONFIGURATION PLUS ANOTHER DOCKING TUNNEL	VEHICLE/MODULE TRANSPORTERS	UMBILICAL SYSTEM – IN HANGAR	UMBILICAL SYSTEM – ON PIER	STORAGE FACILITY PLATFORM AREA	STORAGE FACILITY – EXPANDED PLATFORM AREA	STORAGE FACILITY – PAYLOAD STORAGE AREA	PROPELLANT STORAGE/TRANSFER SYSTEM	AIRLOCK MODULES AM-1	AIRLOCK MODULES AM-2	PORTABLE IVA TUNNEL	MOBILE CHERRYPICKER AND HANDLING TOOLS	BALLUTE/ENGINE TRANSPORTER	CREW MODULE
ORBITER		●	●			●	●								●					●		
TELEOPERATOR	– UNMANNED					●	●			●		●			●					●		
	– MANNED						●			●		●			●					●		●
GROUND-BASED OTV	– UNMANNED			●		●				●		●			●					●		
	– MANNED			●			●			●		●			●		●	●	●	●		●
AEROBRAKED OTV	– UNMANNED				●	●	●			●	●	●	●		●	●				●	●	
	– MANNED				●		●			●	●	●	●		●	●	●	●	●	●	●	●
SINGLE STAGE OTV	– UNMANNED				●	●	●			●	●	●	●		●	●				●	▷2	
	– MANNED				●		●			●	●	●	●		●	●	●	●	●	●	▷2	●
2-STAGE OTV	– UNMANNED				●	●	●			●	●	●	●		●	●				●	▷2	
	– MANNED				●		●			●	●	●	●		●	●	●	●	●	●	▷2	●
1½-STAGE OTV	– UNMANNED				●	●	●		● ▷1	●	●	●	●		●	●				●	▷2	
	– MANNED				●		●		● ▷1	●	●	●	●		●	●	●	●	●	●	▷2	●
SHUTTLE DERIVED VEHICLE	– TYPE A							●						●	●					●		
	– TYPE B							●						●	●					●		

▷1 REQ'D FOR 3 AND 4 DROP TANK VERSIONS ONLY

▷2 TRANSPORTER CONFIGURED FOR ENGINE HANDLING ONLY

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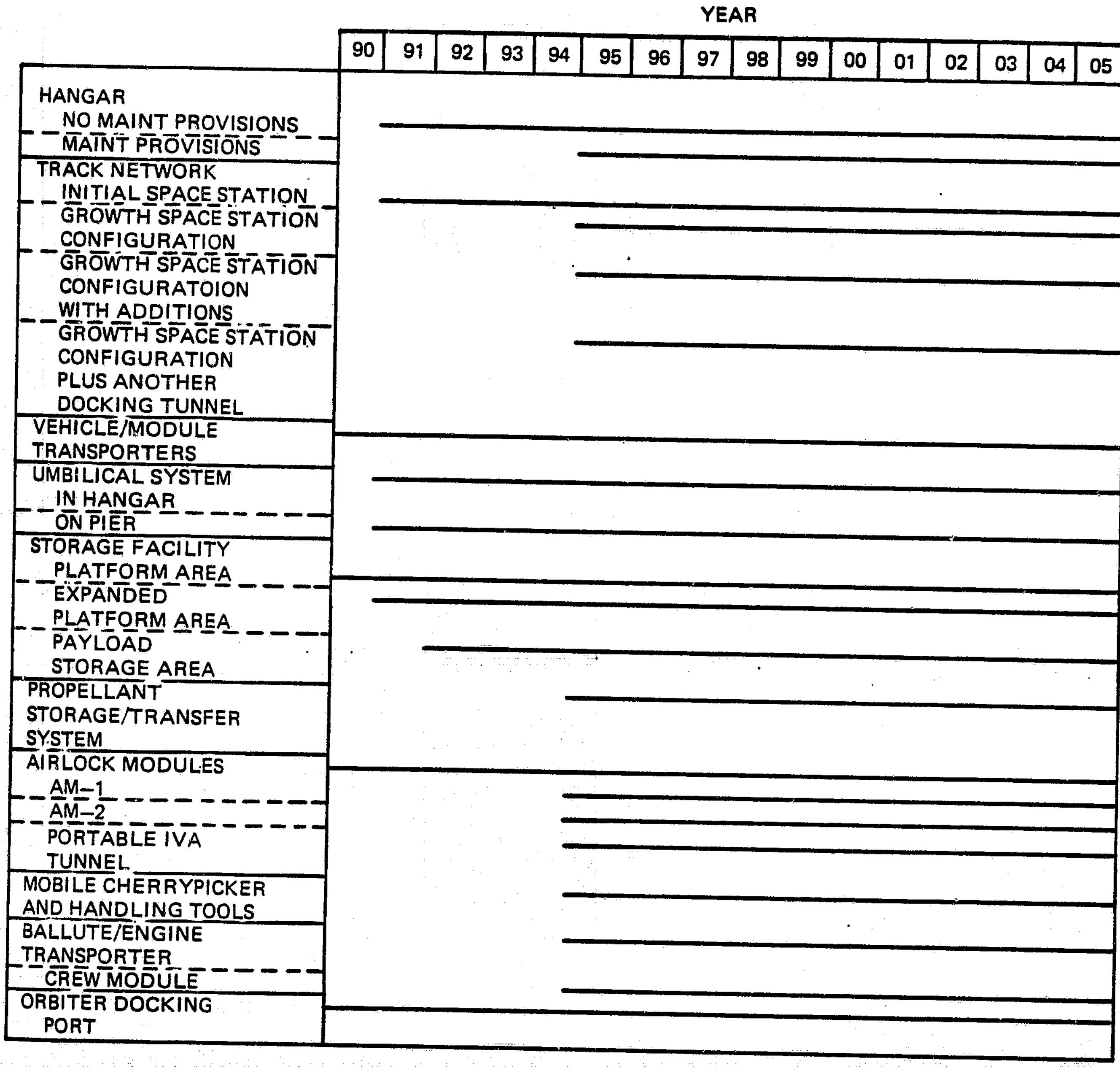

Figure 3.4-4. Time Phased Flight Support Operations Accommodations Requirements

- o Replenishment of raw materials/retrieval of products from an attached materials manufacturing payload
- o Maintenance or refurbishment of spacecraft brought to the space station from their operational orbit location (retrieval and replacement of the spacecraft is included)
- o Specifically excluded from our definition of servicing operations are 1) satellite checkout when no construction operations are required - these are included within the "flight operations" classification, and 2) construction operations.

Remote From The Space Station

- o In-situ resupply, maintenance, or refurbishment of free-flyers and platforms (includes co-orbiting and GEO satellites).

3.4.4.2 Missions Requiring Servicing Operations

Figure 3.4-5 shows the time-phased servicing operations mission model. (Note—The time-phased servicing mission model from the "mission driven scenario," see Sec. 4.2.1 and 5.2.) The source of the identification of the servicing requirements were the mission data forms.

3.4.4.3 Servicing Operations Accommodation Requirements

Figure 3.4-6 shows the time-phased servicing operations accommodations requirements.

FIGURE 3.4-5 SERVICING OPERATIONS MISSION MODEL

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
			TRAFFIC MODEL YEAR															
1	S001	EARTH OBSERV* PALLET				SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM
2	S002	SYNTH APERTURE* RADAR						SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM
3	S003	HETERODYNING* C02 LIDAR									2SM	2SM	2SM	2SM	2SM	2SM	2SM	2SM
4	S004	UPPER ATMOS* RESEARCH PKG								2SM	2SM	2SM	2SM	2SM	2SM	2SM	2SM	2SM
5	0T03	SPACE STATION* MODULES		SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM
7	SP01	SPACE SCIENCE* SUBSATELLITE			IS	IS	IS		IS	IS	IS	IS						
8	SP02	SPACE PHYSICS* PALLET				SM	SM	SM	SM	SM			SM	SM	SM	SM	SM	SM
9	SA01	VLBI/COSMIC* PAY PKG			SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM
10	SL08	RAD BIOLOGY* IN SM MAMMALS								4SM	4SM	4SM	4SM			4SM	4SM	4SM

KEY

SM Servicing/Maintenance of Space Station Modules on Attached Mission Equipment

OS Servicing of Satellites Brought On-Board Space Station

RS Resupply of Coorbiting Platform For Free Flyer

IS In-situ Servicing

* High Inclination Space Station Payloads, All Others Low Incl. Space Station Payloads

FIGURE 3.4-5 SERVICING OPERATIONS MISSION MODEL (Continued)

NO.	KEY	PAYLOAD DESCRIPTION	TRAFFIC MODEL YEAR 90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
11	SL01	HUMAN LIFE SI CARRY-ONS		12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM						
12	SL02	SMALL MAMMALS CARRY-ONS		12SM	12SM	12SM	12SM	12SM										
13	SL03	PLANT DEVEL CARRY-ONS			12SM	12SM	12SM	12SM	12SM	12SM								
14	SL04	LIFESCIENCES RES FAC					12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM
15	SL05	CENTRIFUGE (ADD TO LSFR)					12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM
16	SL06	CLOSED ENV LSS EXPT MOD								12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM	12SM
17	CM01	MATLS SCIENCE LAB			4SM	4SM	4SM	4SM	4SM	4SM	4SM	4SM	4SM	4SM	4SM	4SM	4SM	4SM
18	CM02	CRYSTAL GROWTH FACTORY/PLAT				4IS	4IS	8IS	8IS	12IS	12IS	14IS	14IS	16IS	16IS	18IS	18IS	18IS
19	CM03	CRYSTAL GROWTH RESUP-1					3IS	3IS	3IS									
20	CM04	CRYSTAL GROWTH RESUP-2								3IS	4IS	5IS	5IS	6IS	6IS	6IS	6IS	6IS

KEY

SM Servicing/Maintenance of Space Station Modules on Attached Mission Equipment

OS Servicing of Satellites Brought On-Board Space Station

RS Resupply of Coorbiting Platform For Free Flyer

IS In-situ Servicing

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FIGURE 3.4-5 SERVICING OPERATIONS MISSION MODEL (Continued)

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
									TRAFFIC MODEL YEAR									
21	SA02	ASTRO TELESCOPE CLUSTER		4IS	4IS	4IS	4IS	4IS	4IS		4IS	4IS	4IS	4IS	4IS	4IS		
22	SA03	ASTROPHYSICS FREE-FLYER				OS	OS	OS	OS	OS	OS			OS	OS	OS	OS	OS
23	SA04	ASTROPHYSICS OBSERVATORIES	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS	OS
28	CC05	RECONFIGURABLE COMM. SATELLITE		IS	IS	IS	IS	2IS	3IS	4IS	4IS	4IS	4IS	4IS	4IS	4IS	4IS	4IS
30	CM06	CONTINUOUS FLOW ELECTRO RESUPP	RS	4RS	4RS	5RS	7RS	9RS	11RS	12RS	14RS	16RS	17RS	20RS	20RS	20RS	20RS	20RS
31	CM07	GLASS PROC PLANT			4SM	4SM	4SM	4SM	8SM	8SM	8SM	8SM	12SM	12SM	12SM	16SM	16SM	16SM
32	CM08	GLASSPROC OPTICAL FIBERS RESUPP			2RS	2RS	2RS	3RS	3RS	4RS	5RS	6RS	8RS	10RS	12RS	15RS	15RS	15RS
33	0T01	LOW INCL STA MODULE	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM	SM
35	0T05	HI ACT STA RESUPPLY						2RS	2Rs	2RS	2Rs	2Rs	2Rs	2RS	2RS	2RS	2RS	2RS
46	SA05	LARGE RADIO TELESCOPE											OS	OS	OS	OS	OS	OS

KEY

SM Servicing/Maintenance of Space Station Modules on Attached Mission Equipment

OS Servicing of Satellites Brought On-Board Space Station

RS Resupply of Coorbiting Platform For Free Flyer

IS In-situ Servicing

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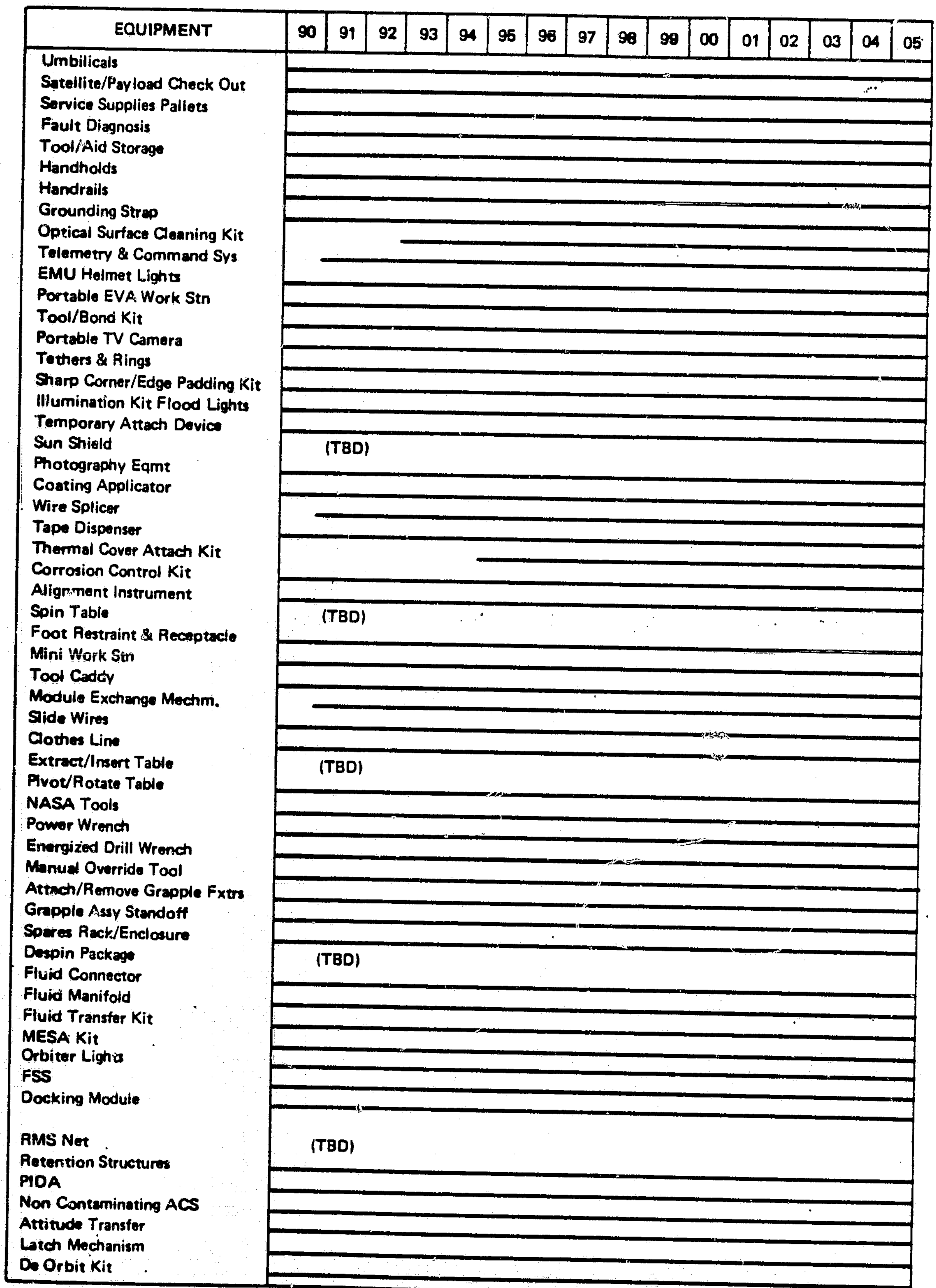

Figure 3.4-6. Servicing Operations Accommodation Requirements (Scenario A – Mission Driven)

4.0 SCENARIOS OF OPERATIONAL CAPABILITY

4.1 INTRODUCTION

In order to create comprehensive time-phased mission models, it is necessary to create scenarios which integrate the user-mission payload deliveries with the space station module deliveries and the associated resupply flights. For our mission model analysis, we have created 3 time-phased scenarios of operational capabilities.

The first scenario is a "mission driven" case wherein the space station system is configured to respond to mission needs. The second scenario is a "station constrained" case wherein the space station system is built up over a longer period of time and missions are deferred until the station configuration is capable of handling the required mission operations. The third scenario is a "no space station" case created for comparison. Mission models that can be served by these three scenarios are given in Section 5.0.

4.2 SCENARIOS

4.2.1 Scenario A -"Mission Driven" Scenario

This scenario responds to the mission demands, i.e., it is a "mission driven" scenario. The space station system is implemented so that it is capable of meeting the accommodation requirements dictated by the payloads in the mission model. The Scenario A has the following operational characteristics and capabilities:

1990 (see fig. 4.2-1)

- o Low Inclination Space Station configured for a crew of 6 is implemented at IOC (2 modules).
- o This station has the following capabilities:
  - o Handling TMS servicing of a co-orbiting materials manufacturing free-flyer. (Electrophoresus Platform)
  - o Servicing of a co-orbiting astrophysics observatory. (Science and Application Lab)

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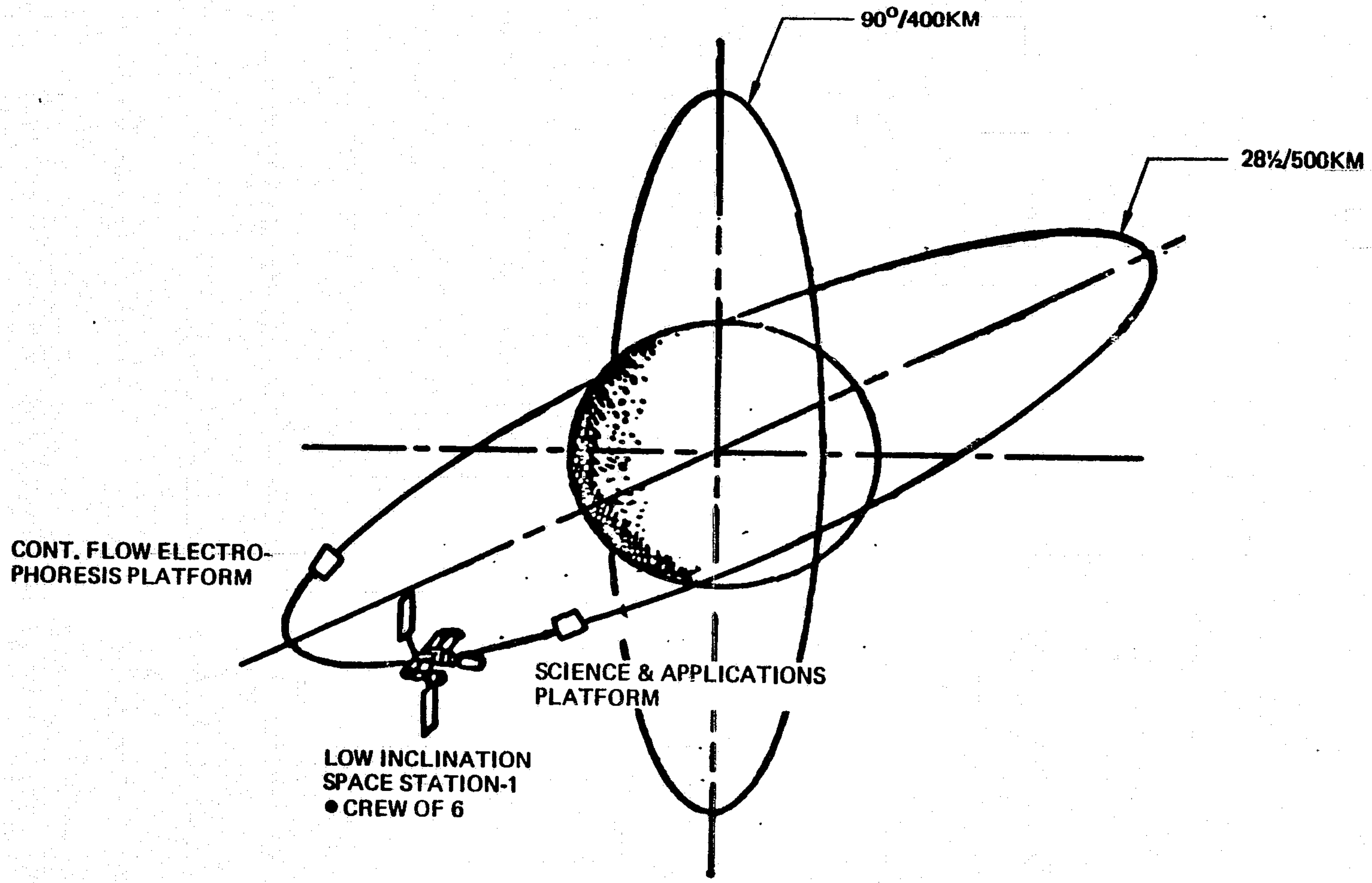

Figure 4.2-1. Scenario A – Year 1990

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1991

- 2 more space station modules are delivered (a habitat and an operations module).
- A crew of 8 is now on-board.
- The station handles the first unmanned science and applications platform payload.
- The first 2 modules of a high inclination space station are delivered and these are manned by a crew of 2.

1992

- A materials research lab module is added to the low inclination space station.
- Two more high inclination space station modules are added to bring it up to full capability for handling earth observation payloads.
- The first earth observation payload is delivered and installed on the high inclination space station.

1993 (see fig. 4.2-2)

- The first crystal growth factory free-flyer is delivered and serviced.
- Another electrophoresis free-flyer is added (total of 2 now in orbit).
- The high inclination space station is now manned by a crew of 3.
- A space science subsatellite is placed into a station-keeping orbit with the high inclination space station.

1995 (see fig. 4.2-3)

1996

- A second low inclination space station is required due to the demand for 16 people.
  - The new station is configured for a crew of 8 and is dedicated to commercial business. Accordingly, it is configured with more solar array so it can provide electrical power service to the commercial customers.
  - The original space station is dedicated to NASA science and applications and technology development missions.

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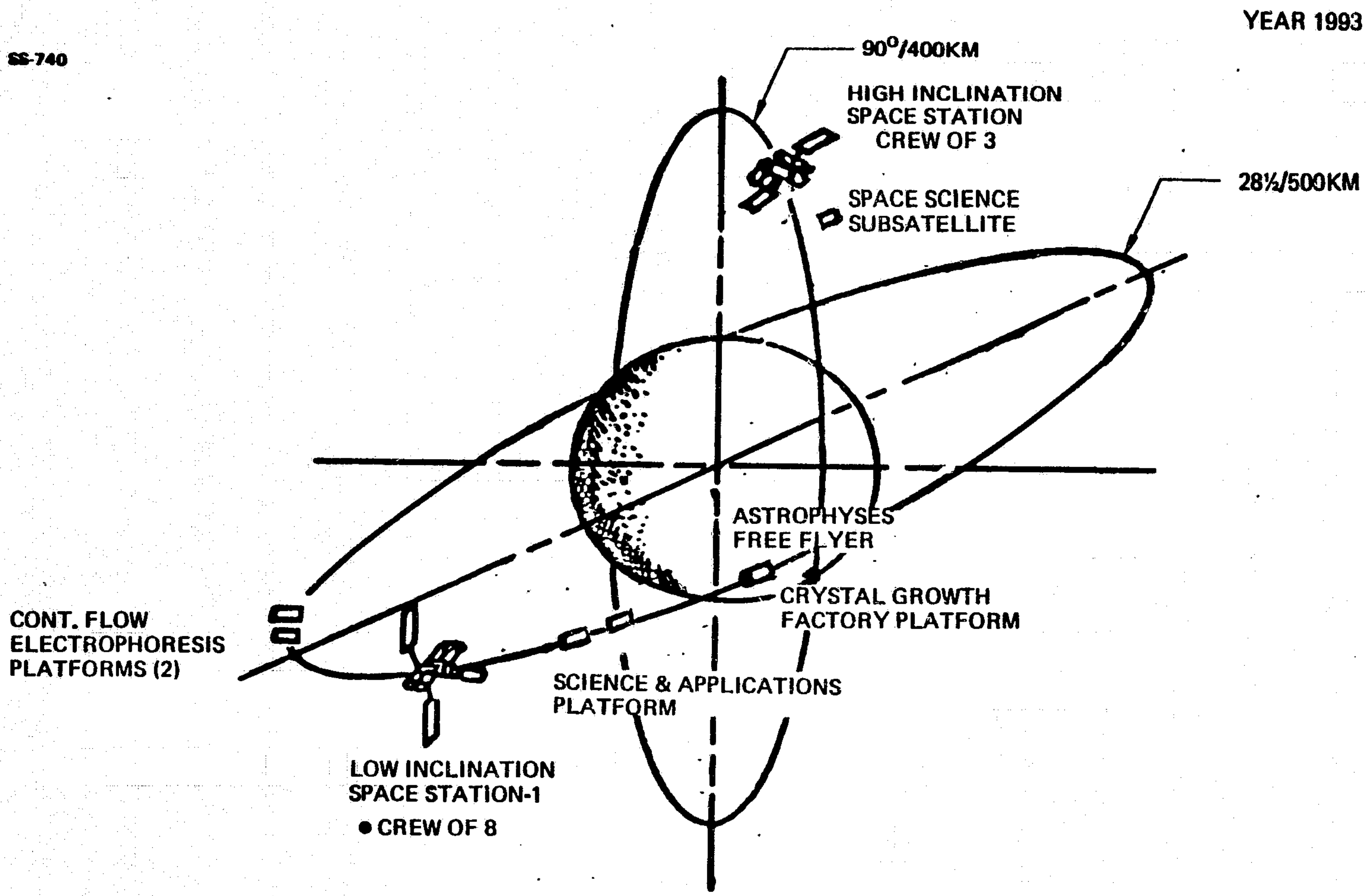

Figure 4.2-2. Scenario A – Year 1993

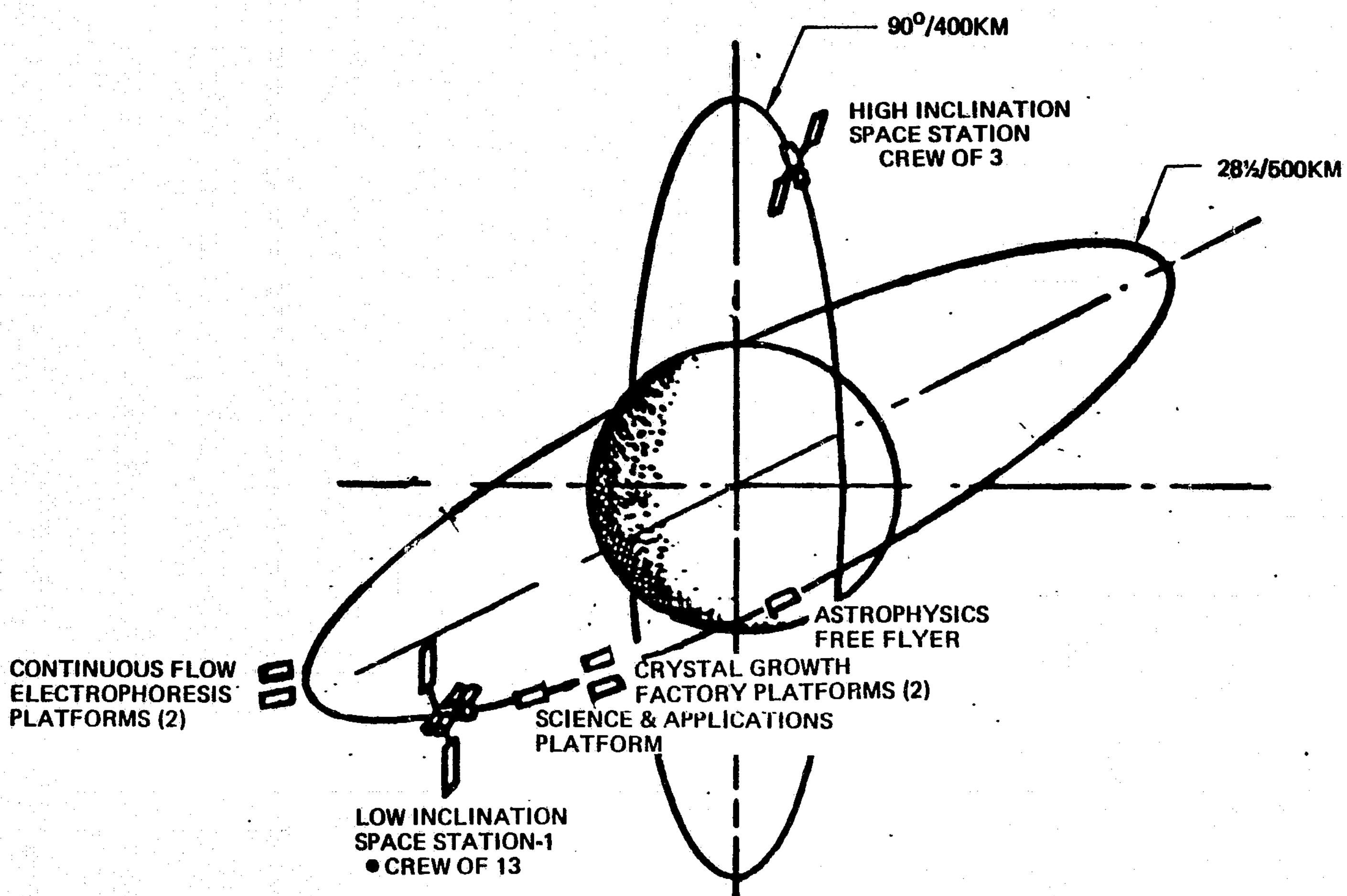

Figure 4.2-3. Scenario A – Year 1995

1997 and on (see fig. 4.2-4 and 4.2-5)

- o The new low inclination space station gradually increases its capabilities and crew size to where it has a crew of 15 in 2002.

4.2.2 Scenario B-"Station Constrained" Scenario

This scenario responds to the probable NASA funding constraints which will stretch out the buildup of the station over a number of years, i.e., it is a "station constrained" scenario. The user missions are delayed until the space station is built up to a configuration capable of handling the required mission operations. The scenario has the following operational characteristics and capabilities:

1990

- o The first low inclination space station module is delivered.
- o No missions are conducted. This is a "shakedown" period where the first module is shuttle-tended while checking out the systems.

1991

- o The second low inclination space station module is delivered.
- o The Logistics Module is delivered with a crew of 3.
- o The only missions conducted this year are carry-on technology demonstration projects and the assembly of the hangar and storage platform.

1992

- o Another low inclination space station module is added to provide experiment and operations support capabilities.
- o A TMS is provided to service a shuttle-launched astrophysics free-flyer.

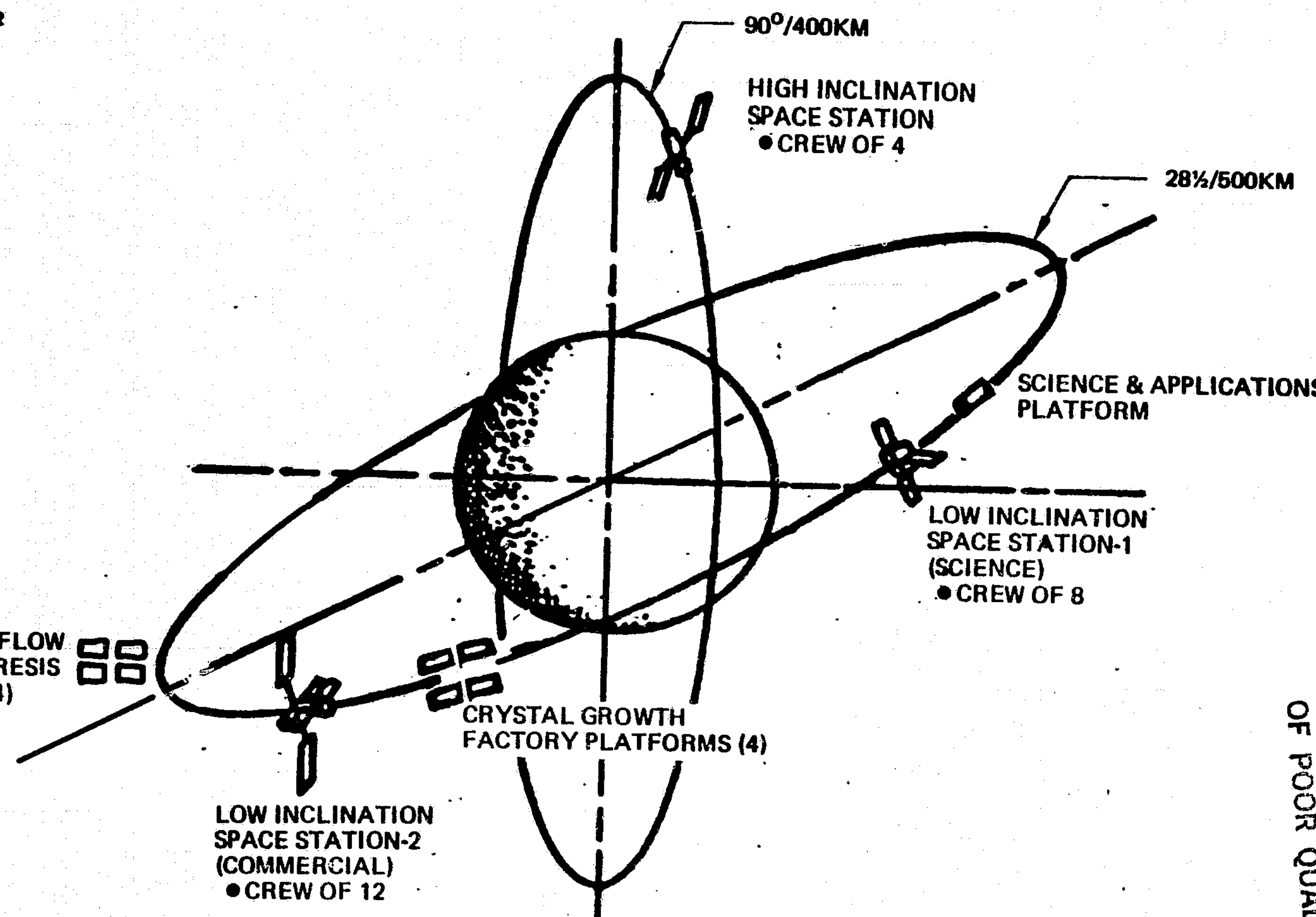

Figure 4.2-4. Scenario A – Year 2000

YEAR 2005

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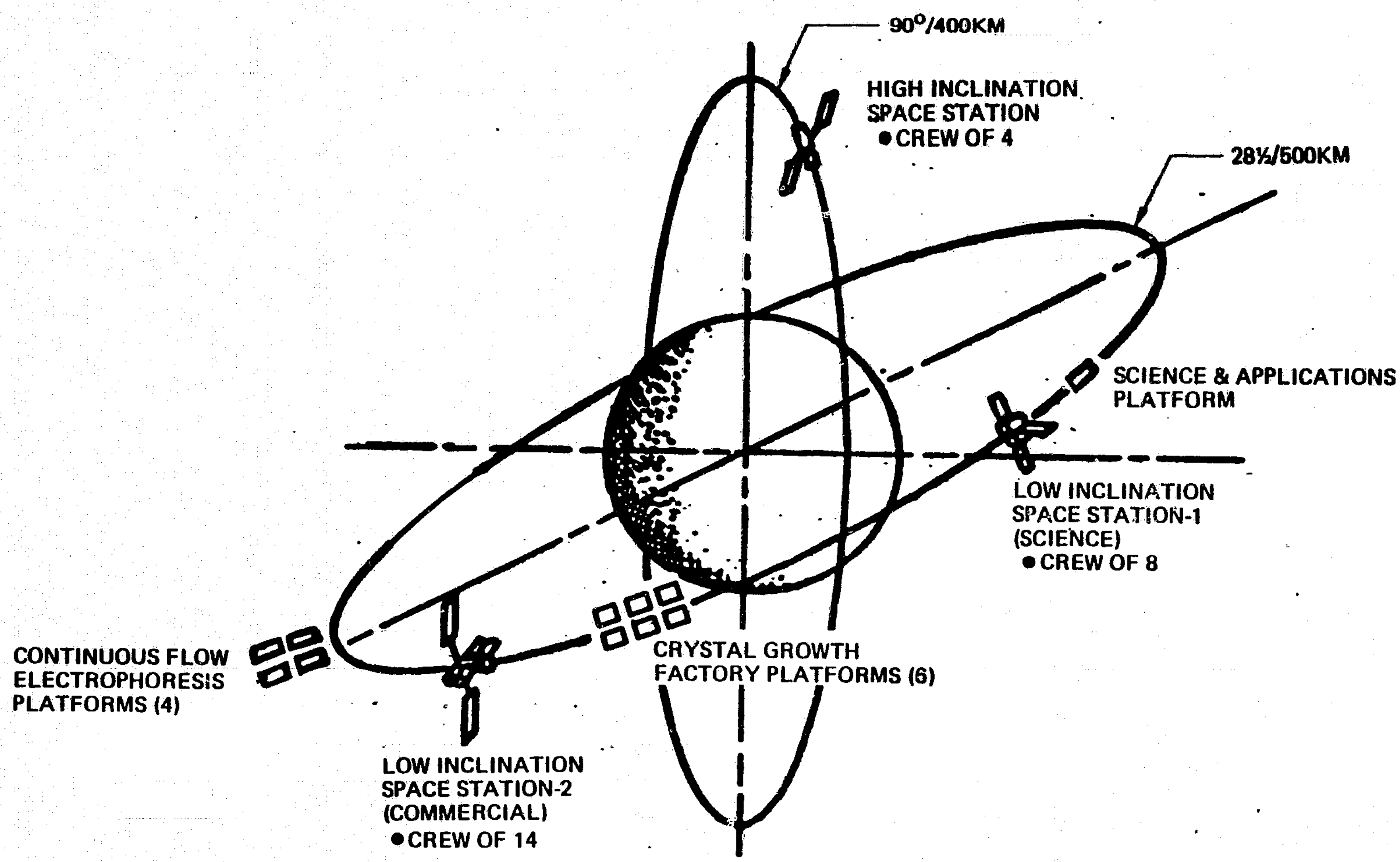

Figure 4.2-5. Scenario A – Year 2005

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1993-1997

- The low inclination space station is expanded to where a crew of 12 can be accommodated.
- Commercial missions are initiated.
- In 1995, the high inclination space station is begun.
- In 1997, the second low inclination space station is started to be assembled.

1998-2005

- The mission traffic builds up to where a crew of 23 is required in LEO in 2002 (15 at a commercial station and 8 at a science station).

4.2.3 Scenario C - "No Space Station" Scenario

This scenario is the "no space station" case. The user missions are allocated to free-flyers or unmanned platforms. The missions that cannot be accomplished without a space station (e.g., some life sciences and technology development missions) are deleted. The mission model is derived from the scenario A mission model.

5.0 SUMMARY OF MISSION REQUIREMENTS

5.1 INTRODUCTION

In the section, the results of the mission analysis integrations are presented. The results are presented in the following sequences:

Scenario A Mission Analysis Results (Section 5.2):

- o Time-phased mission manifest schedule for high and low inclination space stations.
- o Low inclination space station mission analysis results.
  - —Traffic model results (Orbiter, OTV, and TMS utilization data).
  - —Resource Requirements summary (electrical power, internal volume, number of berthing ports).
  - —Crew Utilization requirements summary (crew size, crew skills).
- o High inclination space station mission analysis results.
  - —(Same data summarized as described for low inclination space station).

Scenario B Mission Analysis Results (Section 5.3):

- o (Same subtopics as given above).

No Space Station Mission Analysis Results (Section 5.4):

- o Revised manifest that reflects missions deleted because of no space station.
- o Traffic model results.

Due to the magnitude of data produced for each scenario, we have elected to present the results of only these three scenarios. Other scenarios have been studied, but are not documented herein.

The reader is referred to Volume 7-5, Mission Analysis Data Book, for the computer printouts that contain the data on which the results summarized below are based.

5.2 MISSION-DRIVEN SCENARIO A - SUMMARY OF MISSION REQUIREMENTS

5.2.1 Low Inclination Space Station

5.2.1.1 Manifesting

Mission model A is an integrated mission set composed of science and applications, commercial, and technology development missions. It also includes space station module deliveries and supply flights.

The manifesting schedule for the low inclination space station in this scenario is shown in Figure 5.2-1. The payload characteristics and high inclination are found in Appendix 4.

The initial operation date of a low inclination space station is in 1990. The initial low inclination space station module is manifested in a single shuttle launch, with three more launches for module deliveries in 1990-91. A second low inclination, low earth orbit space station is constructed in 1995-96. Each station requires four resupply missions per year.

5.2.1.2 Traffic Model Results

The traffic model results are shown in Figure 5.2-2. It is apparent from these figures that, after the first few years, the commercial missions grow to dominate the shuttle traffic. The required number of shuttle flights to the low inclination, low earth orbit space station grows steadily from 9 flights in 1990 to about 50 in the 2001-05 time frame. Except for a local peak in 1996 to construct the second low inclination space station, the space station servicing and operations traffic remains steady at 6-10 flights per year. Science missions never exceed the equivalent of one full shuttle flight per year, while communications satellites which use the space station require 3 flights per year after 1994. The commercial materials processing missions quickly come to dominate the traffic, expanding from 2 flights per year in 1990 to over 30 flights per year beyond 2000.

The effect of commercial missions on the traffic model can also be seen when the shuttle fleet size is analyzed. The ideal minimum fleet size depicted here is that fleet size which would be required to sustain the mission schedule if all vehicles operated flawlessly with no

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FLIGHT SUPPORT TRAFFIC MODEL

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
1	S001	EARTH OBSERV PALLET	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	S002	SYNTH APERTURE RADAR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3	S003	HETERODYNING CO2 LIDAR	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
4	S004	UPPER ATMOS RESEARCH PKG	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
5	OT03	SPACE STATION MODULES	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0
6	OT04	HI-INCL STATION RESUPPLY	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2
7	SP01	SPACE SCIENCE SUBSATELLITE	0	0	1	0	-1	0	1	0	0	-1	0	0	0	0	0	0
8	SP02	SPACE PHYSICS PALLET	0	0	0	1	0	0	0	-1	0	0	1	0	0	0	0	0
9	SA01	VLBI/COSMIC RAY PKG	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10	SL09	RAD BIOLOGY IN SM MAMMALS	0	0	0	0	0	0	0	1	0	0	-1	0	0	1	0	0
11	SL01	HUMAN LIFE SI CARRY-ONS	0	1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
12	SL02	SMALL MAMMALS CARRY-ONS	0	1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
13	SL03	PLANT DEVEL CARRY-ONS	0	0	1	0	0	0	0	-1	0	0	0	0	0	0	0	0
14	SL04	LIFESCIENCES RES FAC	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
15	SL05	CENTRIFUGE (ADD TO LSRF)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
16	SL06	CLOSED ENV LSS EXPT 400	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

TRAFFIC MODEL YEAR

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
17	CM01	MATLS SCIENCE LAB	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
18	CM02	CRYSTAL GROWTH FACTORY/PLAT	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	0
19	CM03	CRYSTAL GROWTH RESUP-1	0	0	0	0	3	3	3	0	0	0	0	0	0	0	0	0
20	CM04	CRYSTAL GROWTH RESUP-2	0	0	0	0	0	0	0	3	4	5	5	6	6	6	6	6
21	SA02	ASTRO TELESCOPE CLUSTER	0	1	0	0	0	0	-1	0	1	0	0	0	0	-1	0	0
22	SA03	ASTROPHYSICS FREE-FLYER	0	0	0	1	0	0	0	0	-1	0	0	1	0	0	0	0

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.2-1. Scenario A (Mission-Driven) Mission Manifest Schedule

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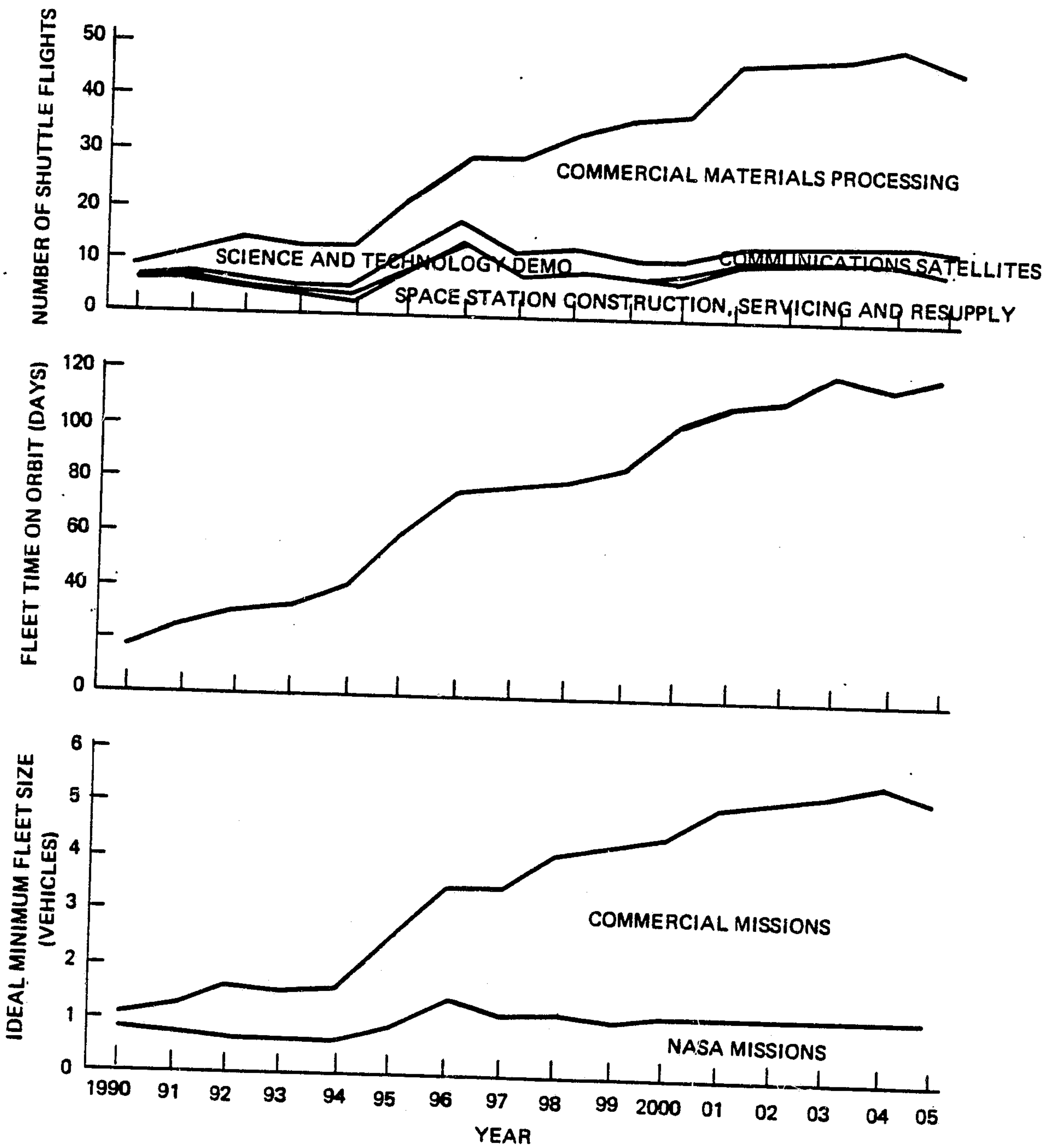

Figure 5.2-2. *Low Inclination Traffic in Mission-Driven Scenario*

C-3

schedule delays. A shuttle turnaround time of 35 working days, with 6-day work-weeks, is assumed for ground operations. The minimum fleet size for NASA missions is 0.6-0.9 in the 1990-95 time frame, and a very steady 1.1-1.2 in 1997 and beyond. These missions include space station construction, servicing, and resupply, science and technology demonstration missions, and OTV/TMS servicing and propellant transfer. The commercial missions, which include communications satellite servicing and assembly as well as materials processing, require a fleet size which increases steadily from 0.24 in 1990 to about 4.5 after 2000.

Figure 5.2-3 illustrates the space-based traffic for the mission-constrained model. Extensive TMS operations are carried out as soon as the first space station is placed in orbit, in 1990. TMS use grows with the high inclination space station, and again with the second low inclination station and the materials processing platforms. The growth is steady, from five flights in 1990 to eighteen per year after 2000. A space-based reusable OTV is needed for communications satellite traffic starting in 1991, with the first reconfigurable satellite in GEO. The OTV is used for communications satellite and for high altitude station resupply. Peak traffic for the OTV is nine flights per year. Figure 5.2-4 shows the OTV propellant delivery data for this mission model.

5.2.1.3 Resource Requirements Summary

The resource mission accommodation requirements for a low inclination space station at 28.5^{o} inclination are summarized in figure 5.2-5. The accommodation requirements are shown in terms of (1) internal (pressurized) volume required, (2) mass at the space station, (3) electrical power required by the experiments and operations and (4) the number of berthing ports required. Of particular importance is the electrical power requirements and the mass at the space station. The power and mass growth versus time are driven by the commercial missions as processing rates increase with time. The payload pointing requirements are contained in Appendix 5-1.

5.2.1.4 Crew Utilization Requirements Summary

Figure 5.2-6 shows the crew size requirements for the low inclination space station mission model. It is seen that a crew size of 6 is required at the first year of operation (1990) and increases to a maximum of 23 people in 2002.

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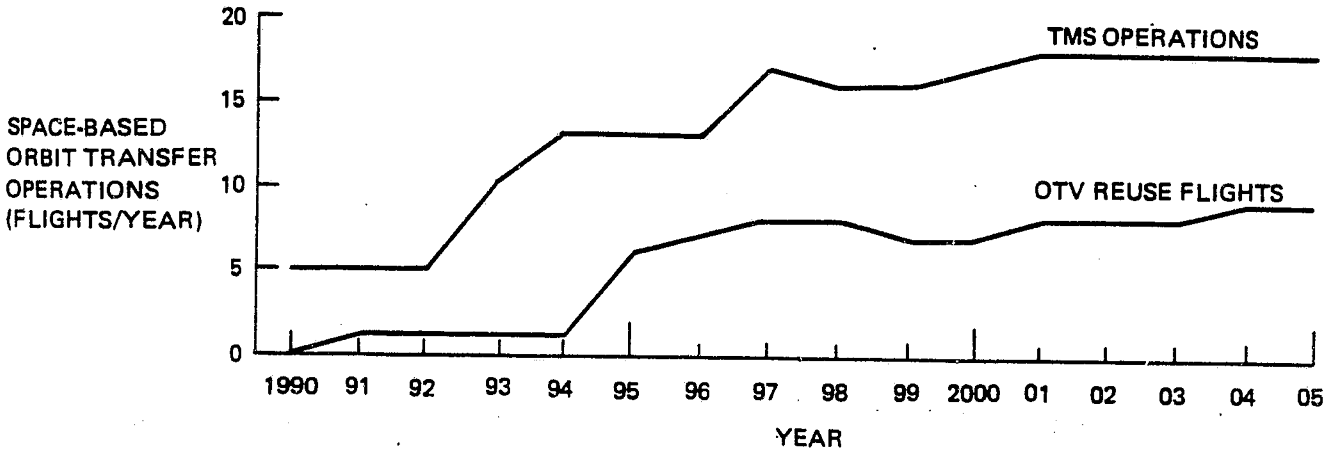

Figure 5.2-3. Space-Based Orbit Transfer Operations Mission-Constrained Traffic Model (Scenario A)

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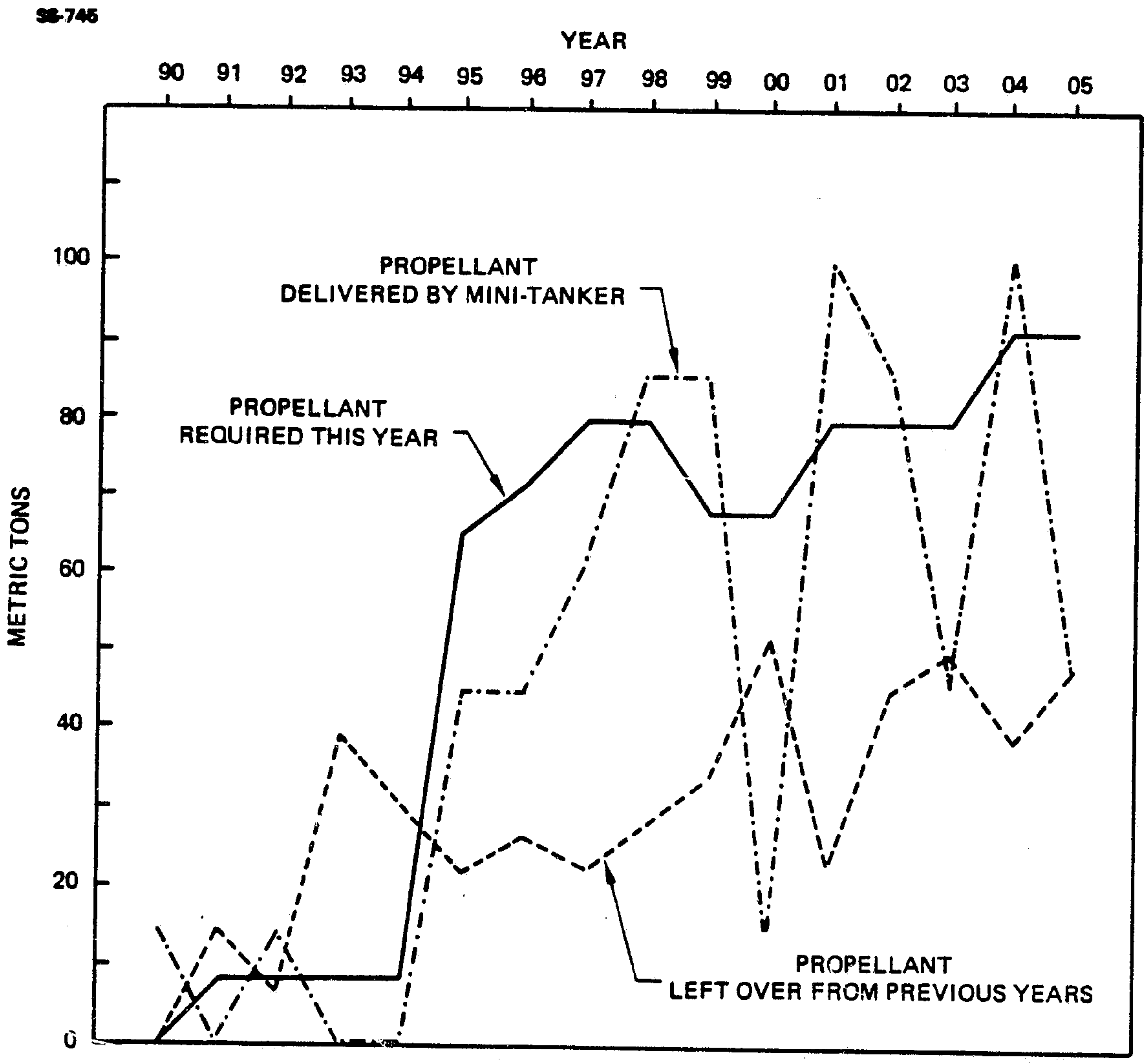

Figure 5.2-4. OTV Propellant Delivery Data (Mission Scenario A)

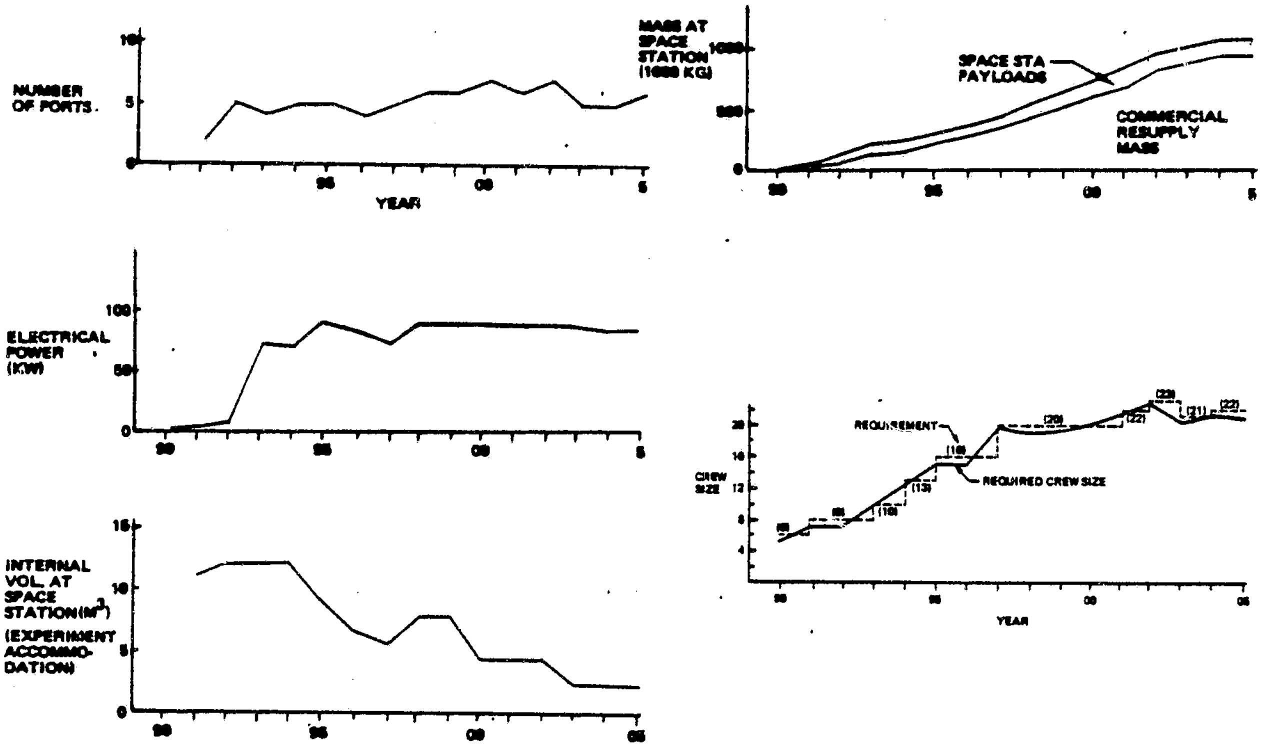

Figure 5.2-5. Low Inclination Mission Accommodation Requirements (Scenario A—Mission Driven)

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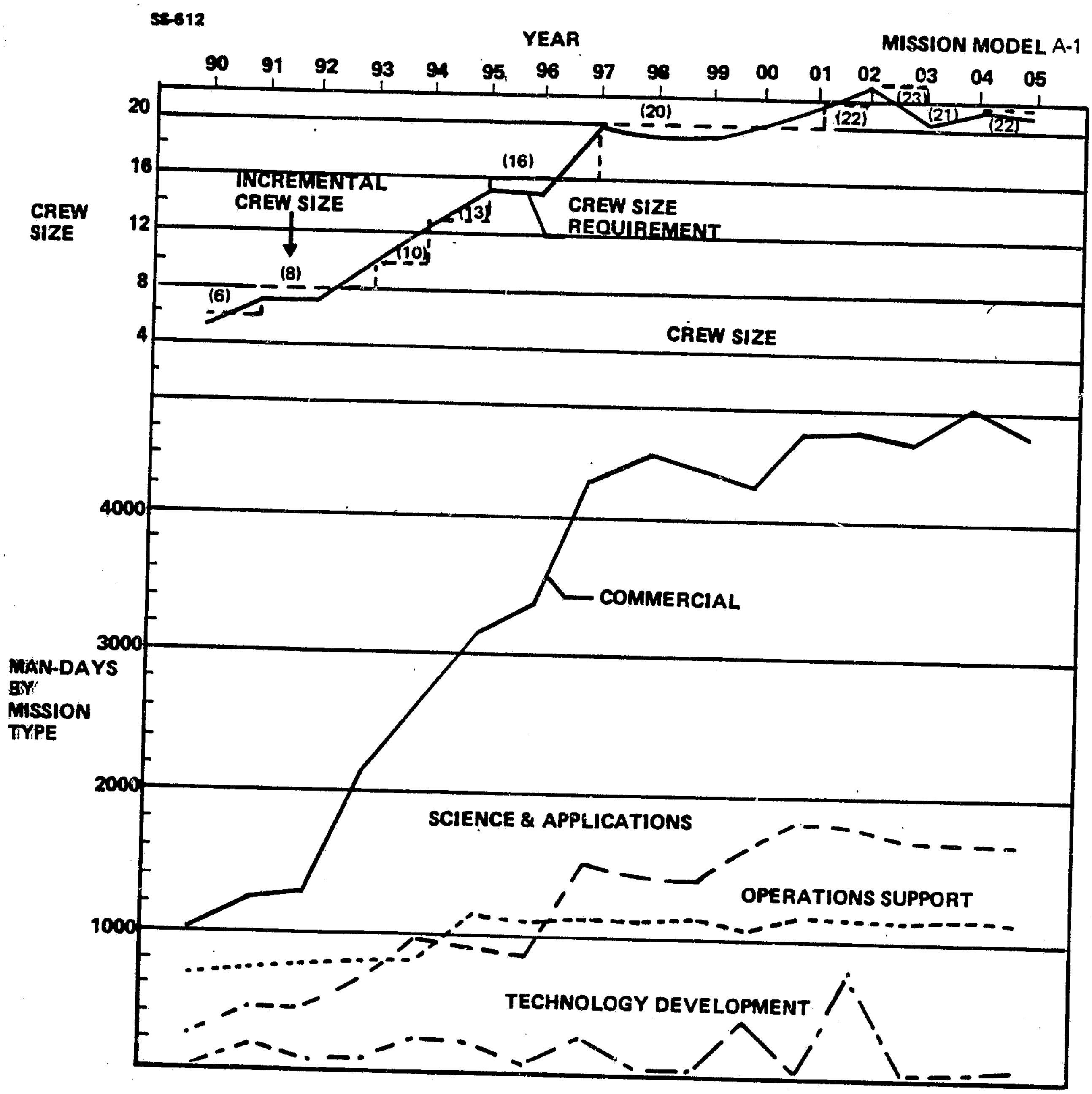

Figure 5.2-6. Low Inclination Mission Crew Accommodation Requirements (Scenario A)

The lower portion of Figure 5.2-6 shows where the demand on the crew comes from. It is seen that tending of commercial payloads is the predominant demand. The science and applications, operations support, and technology demonstration crew demands are relatively modest in comparison.

Figure 5.2-7 shows the time-phased demands on the various crew skills. It is seen that the medical/biological research, spacecraft mechanical and data systems, space station system operations, EVA service, and TMS pilot skills are in the most demand.

5.2.2 High Inclination Space Station

5.2.2.1 Introduction

The high inclination space station is a scientific facility. There are no commercial missions identified for this station in this mission model.

There are a number of scientific missions that require a high inclination space station. These missions include earth observation missions such as land, ocean, and atmospheric observation and monitoring, space science missions to study the near-earth plasma and magnetosphere, and astronomical missions which require sun-synchronous orbits. In the mission-driven scenario, a space station is placed in high inclination orbit in 1991-92, becoming operational after the second shuttle flight. This station requires two resupply flights per year.

5.2.2.2 Manifesting

The high inclination manifesting model is summarized in Table 5.2-1.

5.2.2.3 Traffic Model Results

The traffic model results are shown in Figure 5.2-8. The number of shuttle flights required is two flights per year for module delivery and space station resupply, plus 0.5-1 per year for payload delivery. The ideal minimum fleet size never exceeds 0.5. Although the traffic is light, the impact of the high inclination space station on utilization of scientific payloads is high when one considers that, once an instrument package is placed on the space station,

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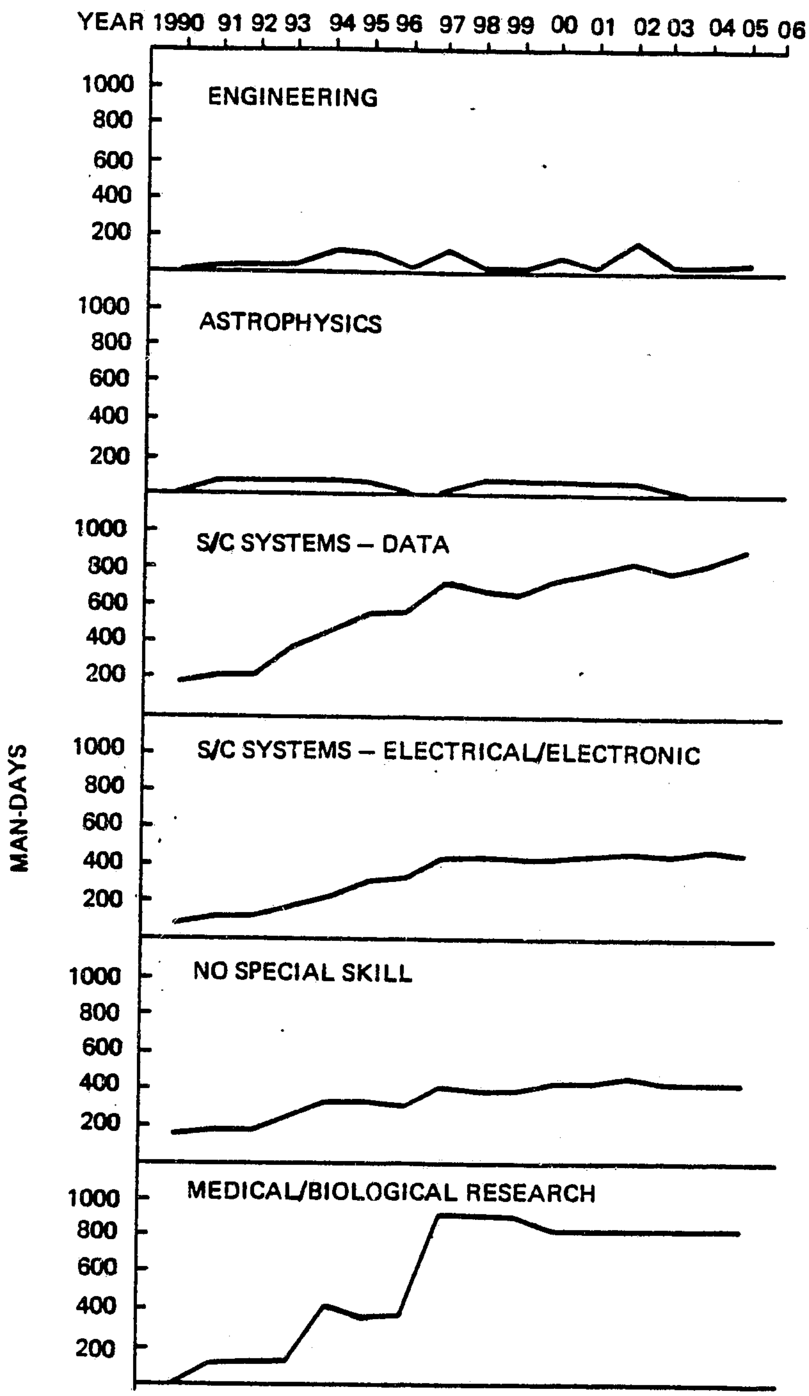

Figure 5.2-7. Low Inclination Space Station Skill Requirements (Scenario A) (Continued)

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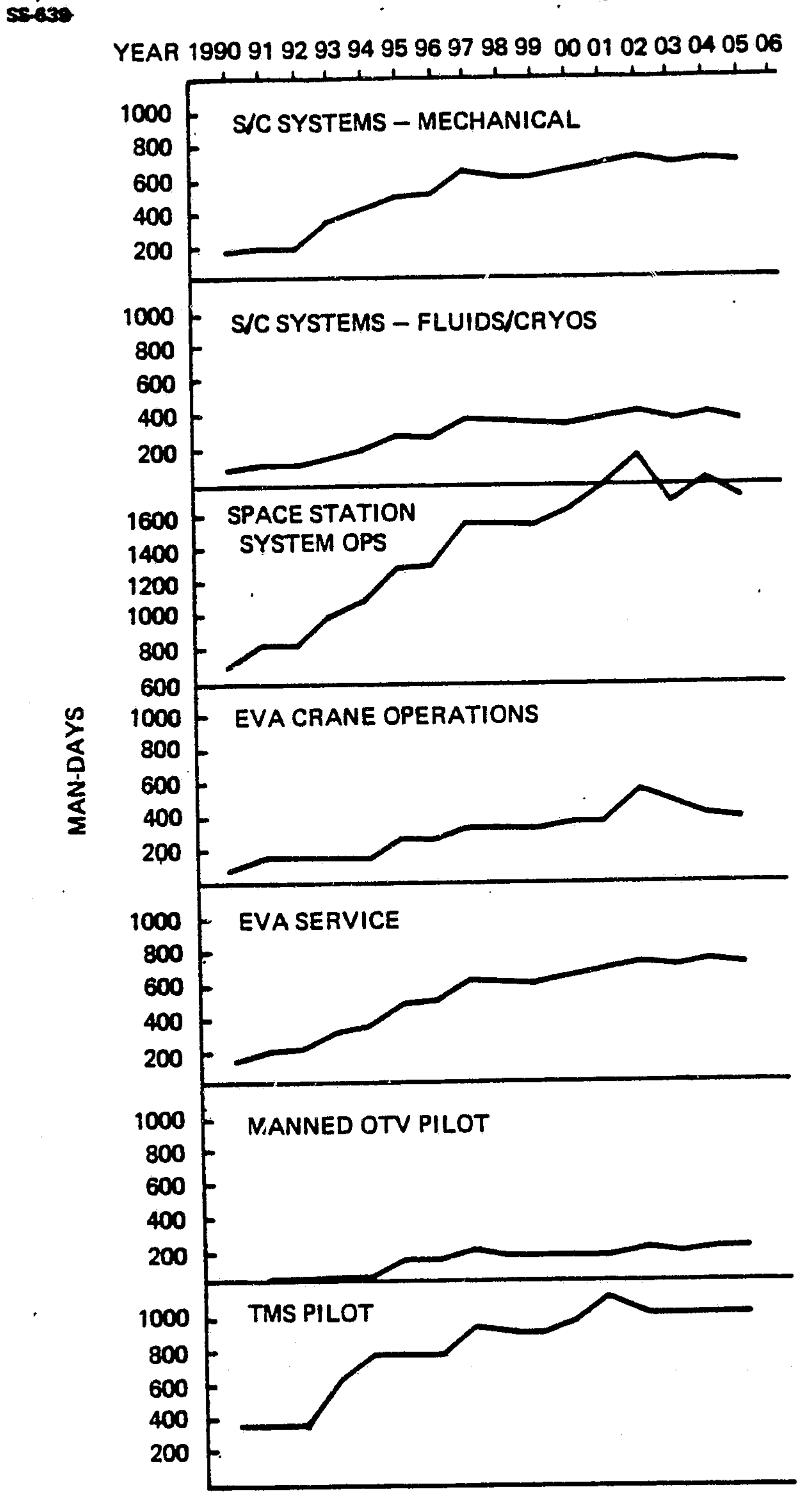

Figure 5.2-7. Low Inclination Space Station Skill Requirements (Continued)

Table 5.2-1. High Inclination Space Station Manifesting Model. Mission Driven Scenario

Year	Payloads
1991	Space Station Modules (2)
1992	Space Station Modules (2) + Space Science Subsatellite
1993	Earth Observations Pallet + Space Physics Pallet + Space Station Module
1994	Very Long Baseline Interferometry/Cosmic Ray Package
1995	Synthetic Aperture Radar
1996	Space Science Subsatellite
1997	Upper Atmosphere Research Package
1998	Heterodyning $C0_2$ Lidar
2000	Space Physical Pallet
1992-1/2 and on	High Inclination Station Resupply (2 per year)

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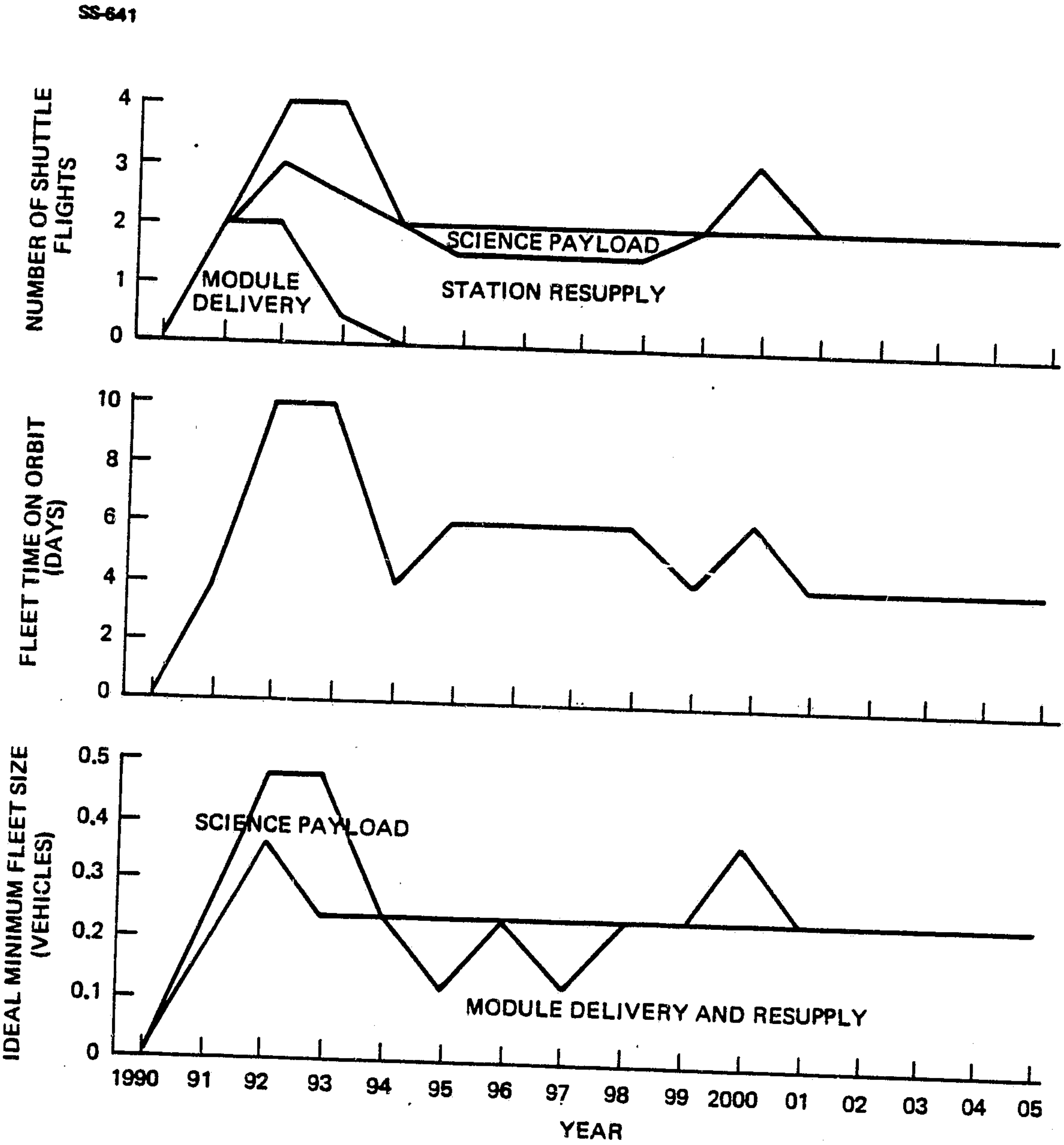

Figure 5.2-8. High Inclination Traffic in Mission-Driven Scenario

it will continue to operate indefinitely. The semiannual resupply visits can be used to repair and service the scientific missions to keep them operating.

5.2.2.4 Resource Requirements Summary

Mission Model A is an integrated mission set composed of science and application, commercial, and technology demonstration missions.

The resource, mission accommodation requirements for a high inclination space station at 98° inclination are summarized in figure 5.2-9. The accommodation requirements are shown in terms of (1) electrical power, (2) number of ports required (3) internal (pressurized) volume required, and (4) the mass at the space station.

Six berthing ports are required by year 2000 with a electrical peak power requirement of 20kw the same year. Internal experiment accommodation volume is $10M^3$ by year 2003. Mass at the Space Station is approximately consistent at 90 metric tons from year 1993 through 2005.

The cost benefit analysis on this space station is given in Section 6.4.

5.2.2.5 Crew Utilization Requirements Summary

Figure 5.2-10 shows the time-phased crew size requirements for the high inclination space station. It is seen that a crew of 2 is required for the year 1991, a crew of 3 for the years 1992-95, and a crew of 4 for 1996 and beyond.

In the lower portion of this figure, it can be seen that the "operations support" is the dominating manpower requirement. Operations support includes orbiter offloading, space station housekeeping, payload installation/removal, etc.

Figure 5.2-11 shows the time-phased skill requirements. Space Station systems operations dominate and earth/ocean observation is second.

The derivation of the above manning requirements and detailed tabulated data are found in Volume 7-5, Mission Analysis Data Book.

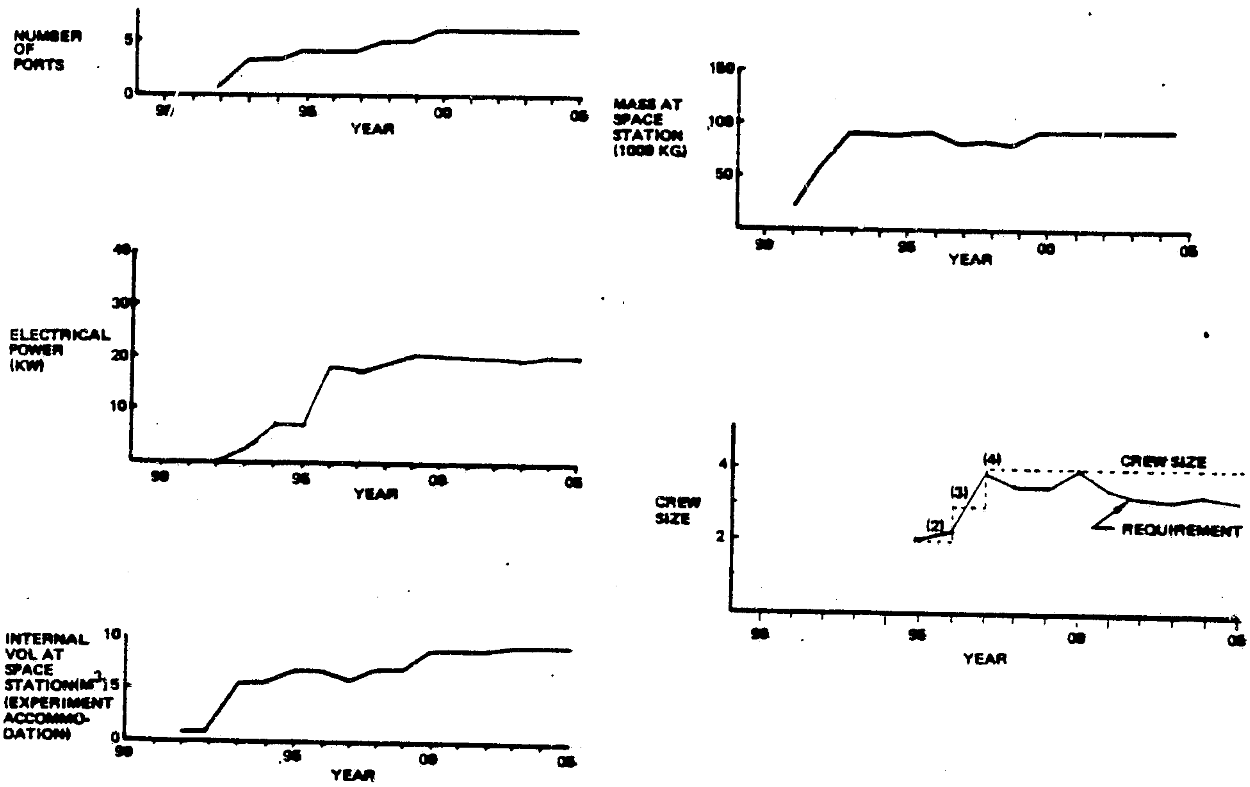

Figure 5.2-9. High Inclination Mission Accommodation Requirements (Scenario A—Mission Driven)

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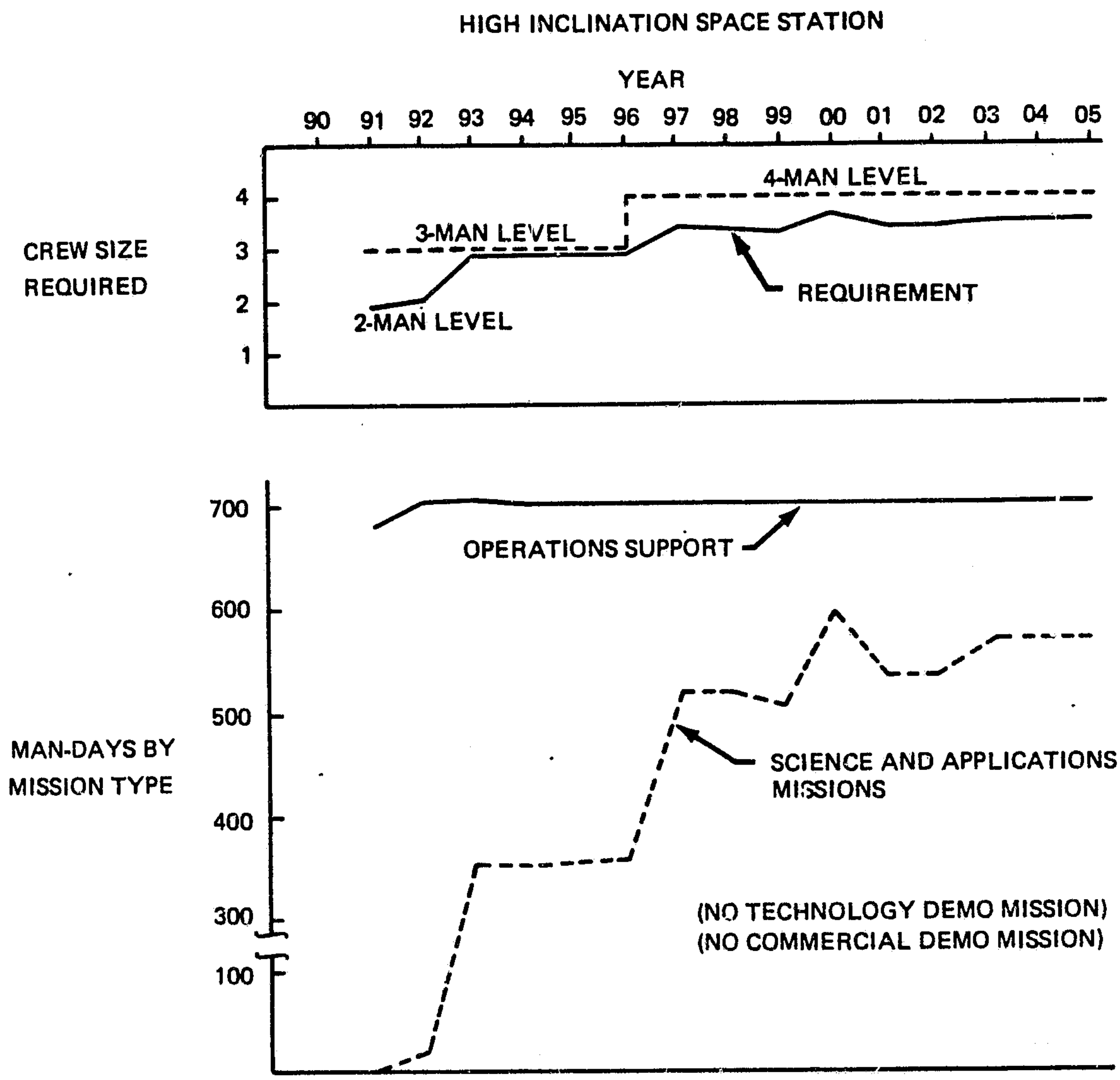

Figure 5.2-10. High Inclination Mission Crew Accommodation Requirements (Scenario A)

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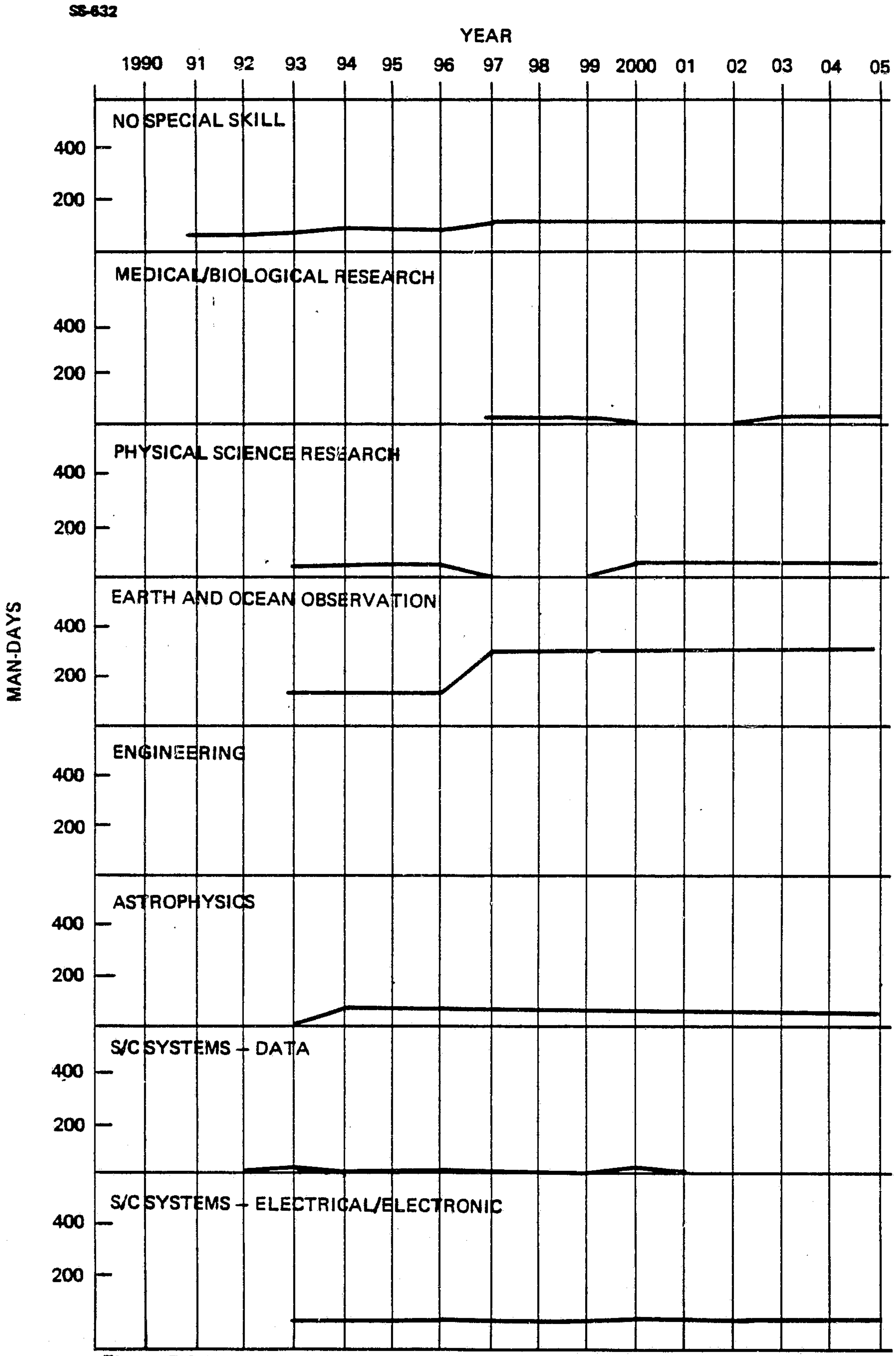

Figure 5.2-11. High Inclination Space Station Skill Requirements (Scenario A)

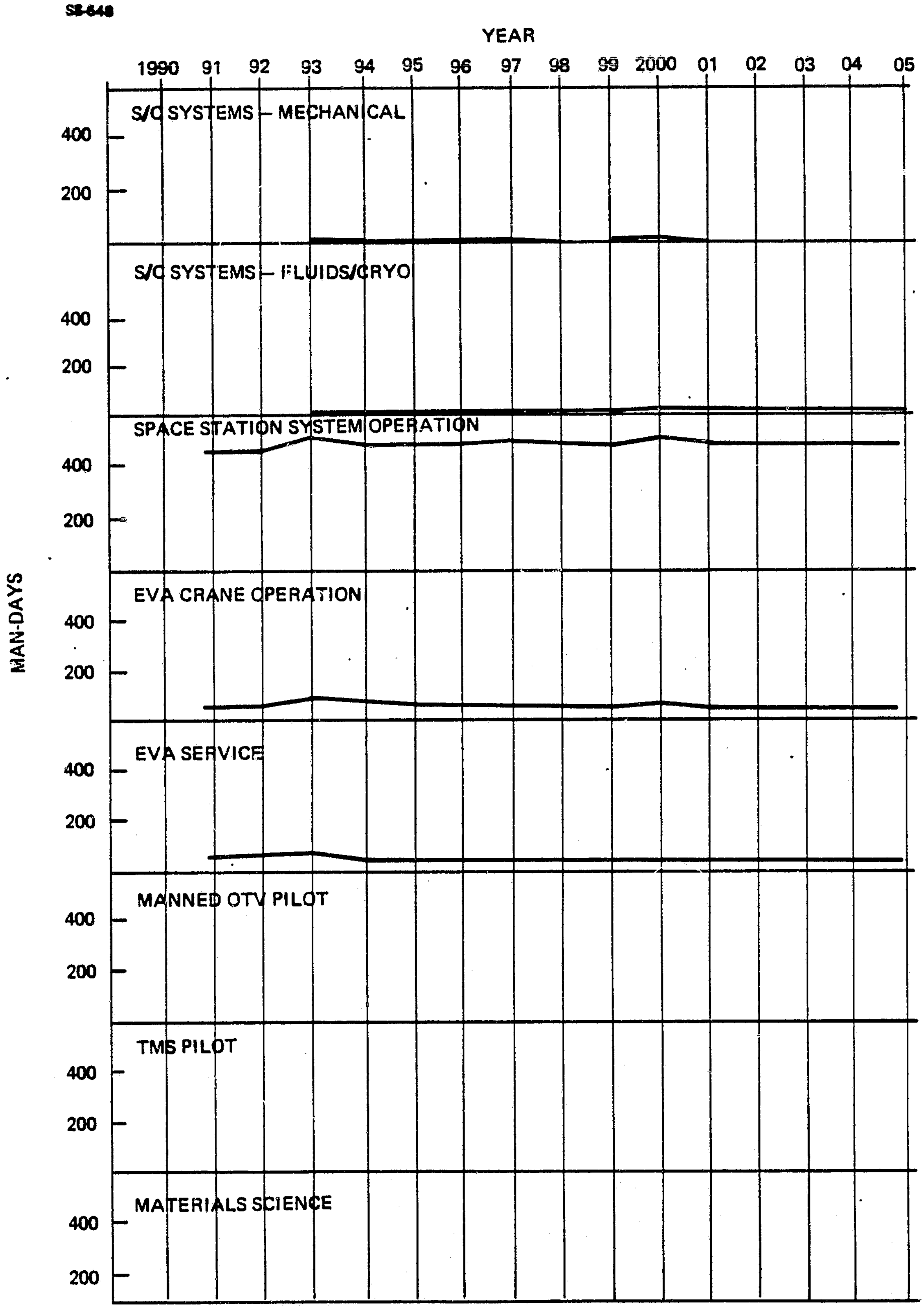

Figure 5.2-11. High Inclination Space Station Skill Requirements (Scenario A) (Continued)

5.3 SPACE STATION DRIVEN SCENARIO - SUMMARY OF MISSION REQUIREMENTS

This scenario describes a space station buildup sequence which is constrained by the space station budget. Rather than mission scheduling being determined by external factors, the space station budget is limited and the missions are manifested when the space station can first accommodate them. Figure 5.3-1 lists the mission manifest schedule for Scenario B. In this scenario, only one space station module is delivered each year. The first low inclination station buildup starts in 1990, but the second does not start until 2003. The high inclination station buildup is delayed until 1995, and the first operational capability begins in 1996.

5.3.1 Low Inclination Space Station

5.3.1.1 Traffic Model Results

The low inclination traffic in the space station driven case is considerably below that in the mission driven scenario at all times. By delaying the actual operation and buildup of the low inclination space station, the commercial traffic is substantially reduced. Figure 5.3-2 shows the results. Communications satellite traffic is delayed by 5-6 years, beginning in 1996 and increasing to three shuttle flights per year by 2001, compared to 1991 and 1995 respectively. The first commercial materials processing at the space station is initiated in 1993 instead of 1990, and the growth rate is slower. The decrease in commercial traffic also permits a decrease in space station servicing and resupply missions. These results are shown in Figure 5.2-2, and the two scenarios are compared.

The savings in ideal minimum fleet size is about 1-2 vehicles, again driven by the loss in commercial traffic. The savings to NASA is in the neighborhood of one-half of one vehicle.

Figure 5.3-3 illustrates the space-based traffic for the space station constrained model. TMS operations are delayed until 1992, but the time-phased traffic is identical to the mission-constrained model in 1993 and beyond. OTV traffic does not begin until 1996, and grows at a considerably slower rate, peaking at eight flights per year. The OTV propellant delivery requirements are shown in Figure 5.3-4.

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FLIGHT SUPPORT TRAFFIC MODEL

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
			TRAFFIC MODEL YEAR															
1	S001	EARTH OBSERV PALLET	C	C	0	C	C	0	0	1	C	C	C	C	C	C	C	C
2	S002	SYNTH APERTURE RADAR	0	C	0	0	C	0	0	C	C	1	C	C	C	C	C	C
3	S003	HETERODYNING CO2 LIDAR	0	C	0	0	0	0	0	C	C	C	C	C	1	C	C	C
4	S004	UPPER ATMOS RESEARCH PKG	C	C	0	0	0	0	0	1	C	C	C	C	C	C	C	C
5	OT03	SPACE STATION MODULES	0	C	0	0	0	1	1	1	1	1	C	C	C	C	C	C
6	OT04	HI-INCL STATION RESUPPLY	C	C	0	C	C	1	2	2	2	2	2	2	2	2	2	2
7	SP01	SPACE SCIENCE SUBSATELLITE	C	C	0	0	C	0	0	C	C	C	1	C	-1	C	1	C
8	SP02	SPACE PHYSICS PALLET	0	C	C	0	0	0	0	1	C	C	C	-1	C	C	C	C
9	SA01	VLBI/COSMIC RAY PKG	0	C	0	0	C	0	1	C	C	C	C	C	0	C	C	C
10	SL08	RAD BIOLOGY IN SM MAMMALS	0	C	C	0	0	0	0	C	C	C	C	1	C	C	C	-1
11	SL01	HUMAN LIFE SI CARRY-ONS	C	0	0	C	0	0	1	C	C	C	C	C	C	C	C	C
12	SL02	SMALL MAMMALS CARRY-ONS	0	C	0	0	C	0	1	C	C	C	C	-1	C	C	C	C
13	SL03	PLANT DEVEL CARRY-ONS	0	C	1	0	C	0	0	C	C	C	-1	C	C	C	C	C
14	SL04	LIFESCIENCES RES FAC	C	C	C	C	C	0	0	1	C	C	C	C	C	C	C	C
15	SL05	CENTRIFUGE (ADD TO LSRF)	0	C	0	C	C	0	C	C	1	C	C	C	C	C	C	C
16	SL06	CLOSED ENV LSS EXPT MOD	0	C	0	0	0	0	0	C	C	1	C	C	C	C	C	C
17	CM01	MATLS SCIENCE LAB	0	C	1	C	C	0	0	C	C	C	C	C	C	C	C	C
18	CM02	CRYSTAL GROWTH FACTORY/PLAT	0	C	0	1	0	1	0	1	C	1	C	1	C	1	C	C
19	CM03	CRYSTAL GROWTH RESUP-1	0	C	0	0	3	3	3	C	C	C	C	C	C	C	C	C
20	CM04	CRYSTAL GROWTH RESUP-2	0	C	0	0	C	0	0	3	4	5	5	6	6	6	6	6

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.3-1 Scenario B (Station-Driven) Mission Manifest Schedule

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	C	1	2	3	4	5
									TRAFFIC MODEL YEAR									
21	SA02	ASTRO TELESCOPE CLUSTER	0	C	0	C	C	1	0	C	C	0	-1	C	C	1	C	C
22	SA03	ASTROPHYSICS FREE-FLYER	C	C	0	1	C	0	0	C	-1	C	C	1	C	C	C	C
23	SA04	ASTROPHYSICS OBSERVATORIES	C	C	1	C	C	0	0	C	C	C	C	C	C	C	C	C
26	CC03	INTELSAT-7,7A CLASS COMSAT	0	C	0	0	C	0	1	1	1	1	1	1	1	1	2	2
27	CC04	MULTIBEAM COMM. SATELLITE	0	C	0	0	0	0	0	1	1	1	1	1	1	C	1	1
28	CC05	RECONFIGURABLE COMM. SATELLITE	C	C	0	C	C	0	1	1	1	1	2	3	4	4	4	4
29	CM05	CONT FLOW ELECTROPH PLATFORM	0	C	0	1	C	0	1	C	C	C	1	C	C	C	C	C
30	CM06	CONTINUOUS FLOW ELECTRC RESUPP	C	C	0	1	4	4	5	7	9	11	12	14	16	17	2C	2C
33	OT01	LOW INCL STA MODULE DEL	1	1	1	1	1	0	0	1	1	1	C	C	C	C	C	C
34	OT02	LOW INCL STA RESUPPLY	0	2	4	4	4	4	4	4	8	8	8	8	8	8	8	8
35	OT05	HI-ALT STA RESUPPLY	C	C	0	C	C	0	0	C	C	2	2	2	2	2	2	2
36	TM01	CONSTR,STORAGE, & HANGAR	0	1	-1	0	0	0	0	C	C	C	C	C	C	C	C	C
37	TP01	PROP TRANSFER & STORAGE	0	C	1	-1	0	0	0	C	C	C	C	C	C	C	C	C
38	TP02	OTV MAINT TECH DEMOS	0	C	0	1	-1	0	0	C	C	C	C	C	C	C	C	C
39	TS01	SATELLITE ASSY & SERVICE	C	C	C	C	1	-1	0	C	C	C	C	C	C	C	C	C
40	TE01	LARGE POWER SYS TECHNOLOGY	C	C	C	0	C	1	-1	C	C	C	C	C	C	C	C	C
41	TC01	ROBOTICS TECH DEMO	C	C	0	C	C	0	0	1	-1	C	C	C	C	C	C	C
42	TM02	PRECISION OPT CONSTR & TEST	C	C	0	0	0	0	0	C	C	C	1	-1	C	C	C	C
43	TM03	PASSIVE MICW RADIOMETER	0	C	0	0	0	0	0	C	C	C	C	C	1	-1	C	C
44	TE02	LIQ DROPLET RADIATOR	0	C	0	C	C	0	0	C	C	C	C	C	C	C	C	1
45	TS01	TECH DEVEL CARRY-ONS	0	1	0	C	C	0	0	C	C	C	C	C	C	C	C	C
46	SA05	LARGE RADIO TELESCOPE	0	C	0	C	0	0	0	C	C	C	1	C	C	C	C	C

NOTE:
PAYLOAD CHARACTERIST
ARE FOUND IN
APPENDIX 4

Figure 5.3-1 Scenario B (Station-Driven) Mission Manifest Schedule (Continued)

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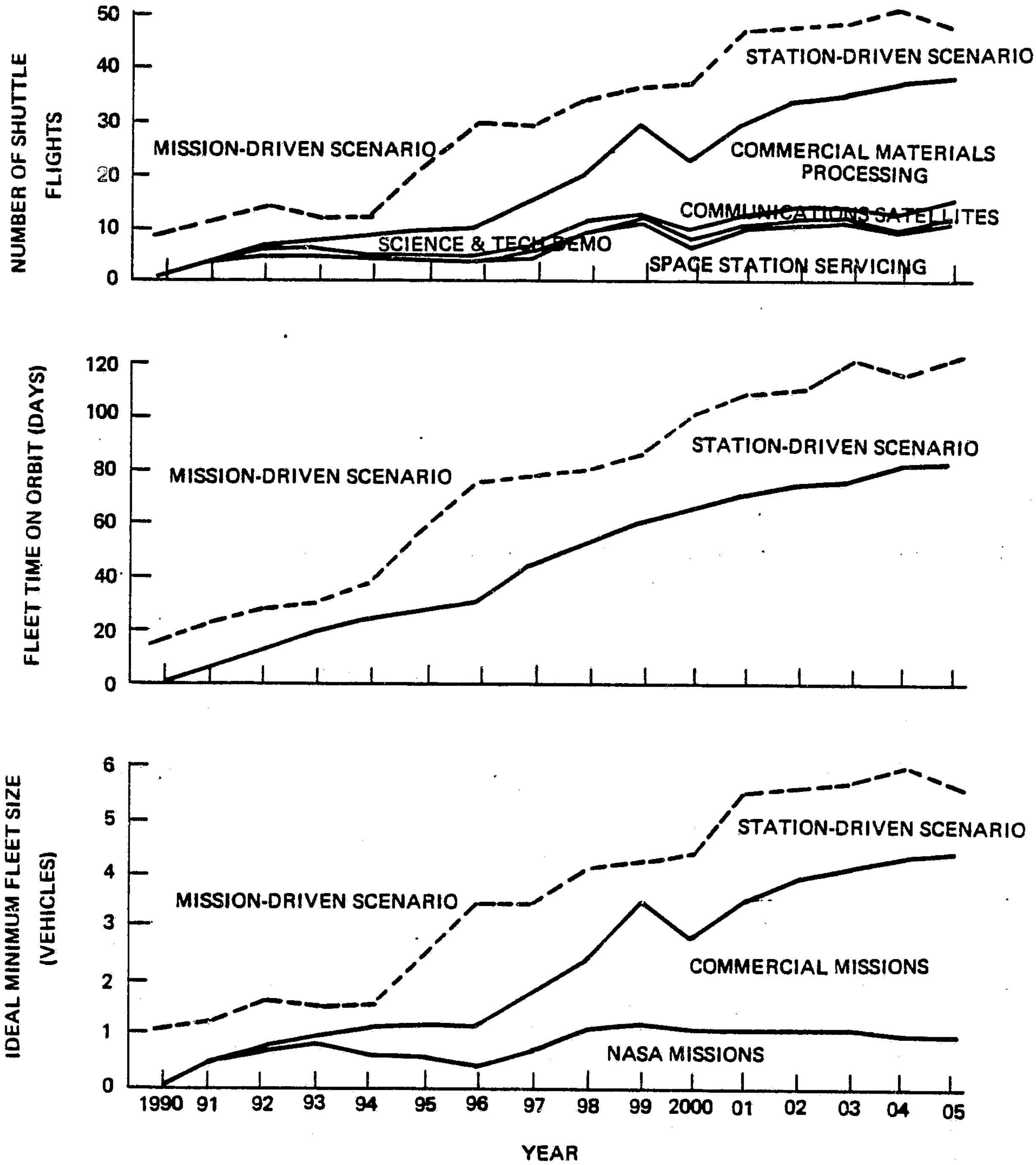

Figure 5.3-2 . Low Inclination Traffic in Space Station-Driven Scenario

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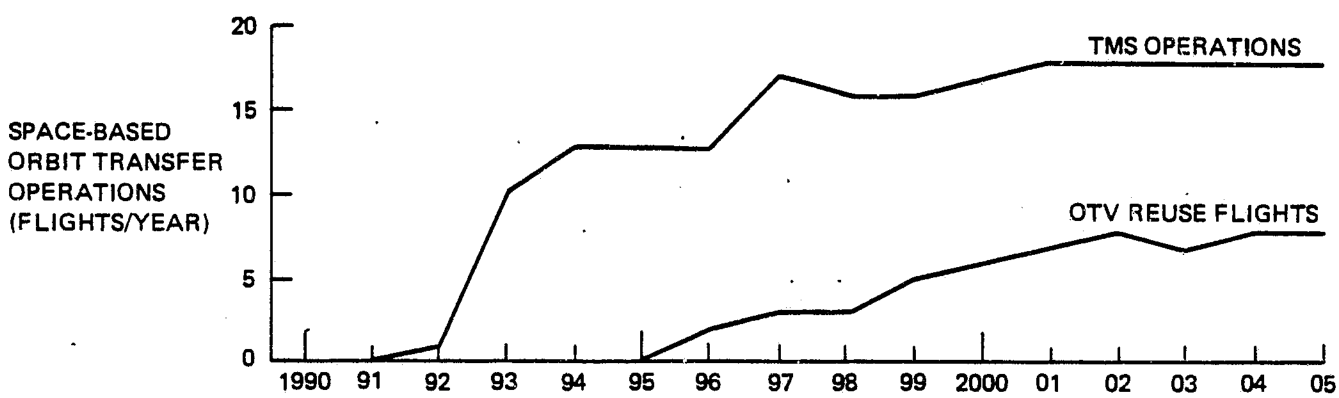

Figure 5.3-3. Space-Based Orbit Transfer Operations Space Station-Constrained Traffic Model (Scenario B)

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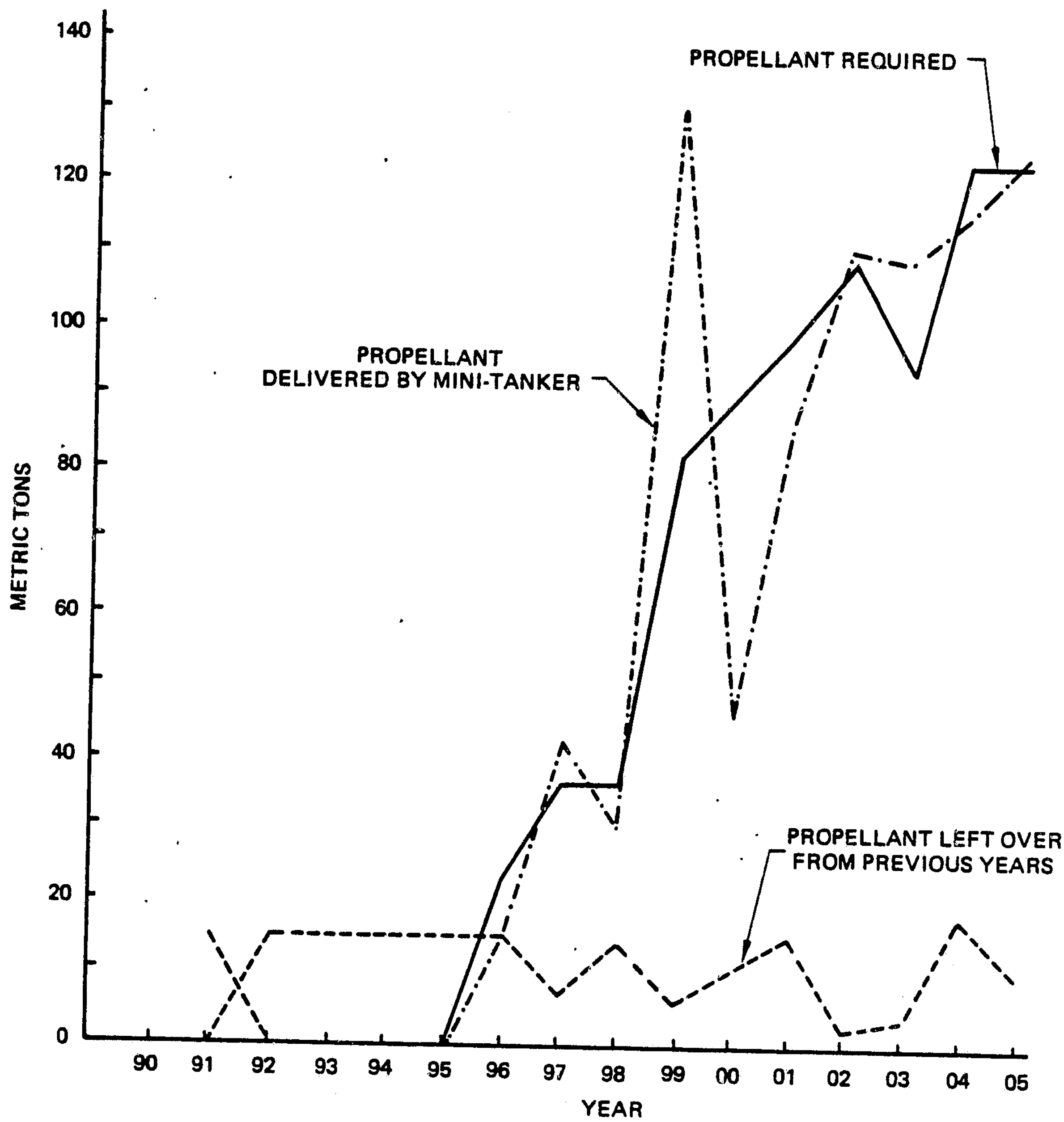

Figure 5.3-4 OTV Propellant Delivery Data (Scenario B)

5.3.1.2 Resource Summary

Mission Scenario B is a station driven integrated mission set composed of science and applications, commercial and technology development missions.

The resource mission accommodation requirement for a low inclination space station at 28.5° inclination are summarized in Figure 5.3-5. The accommodation requirements are shown in terms of (1) internal (pressurized) volume required, (2) mass at the space station, (3) electrical power required by the experiments and operations, and (4) the number of berthing ports required. Mass is driven by the commercial missions resupply as indicated. Power requirements are reasonably constant at approximately 85 kW beginning in 1997. The internal volume requirements are quite low due to the addition of an LSRF module and a CELSS module added in 1997 and 1999, respectively; berthing ports do not exceed five.

5.3.1.3 Crew Utilization Requirements Summary

Figure 5.3-6 shows the crew size requirements for the low inclination space station for Scenario B. It is seen that the crew size starts out in 1990 at 2, increases to a crew of 3 in 1991-2, and then jumps to a crew size of 9 in 1993. Over the next 3 years, the crew size increases to 12. In 1997, a second space station is required in LEO when the total crew size requirement increases to 16. The maximum crew size in this Scenario B occurs in 2002 when a total LEO crew size of 23 is required. This crew size would be split into a crew of 15 at the second space station, which would be dedicated to commercial, technology demonstration, and space operations missions, and a crew of 8 will be located in the original space station which will now be dedicated to science and applications and technology demonstration missions.

The division of crew time by mission type is shown in the lower portion of Figure 5.3-6. As in Scenario A, the commercial operations dominate the demand on the crew.

Figure 5.3-7 shows a year-by-year comparison of the crew size and crew activity requirements of Scenarios A and B.

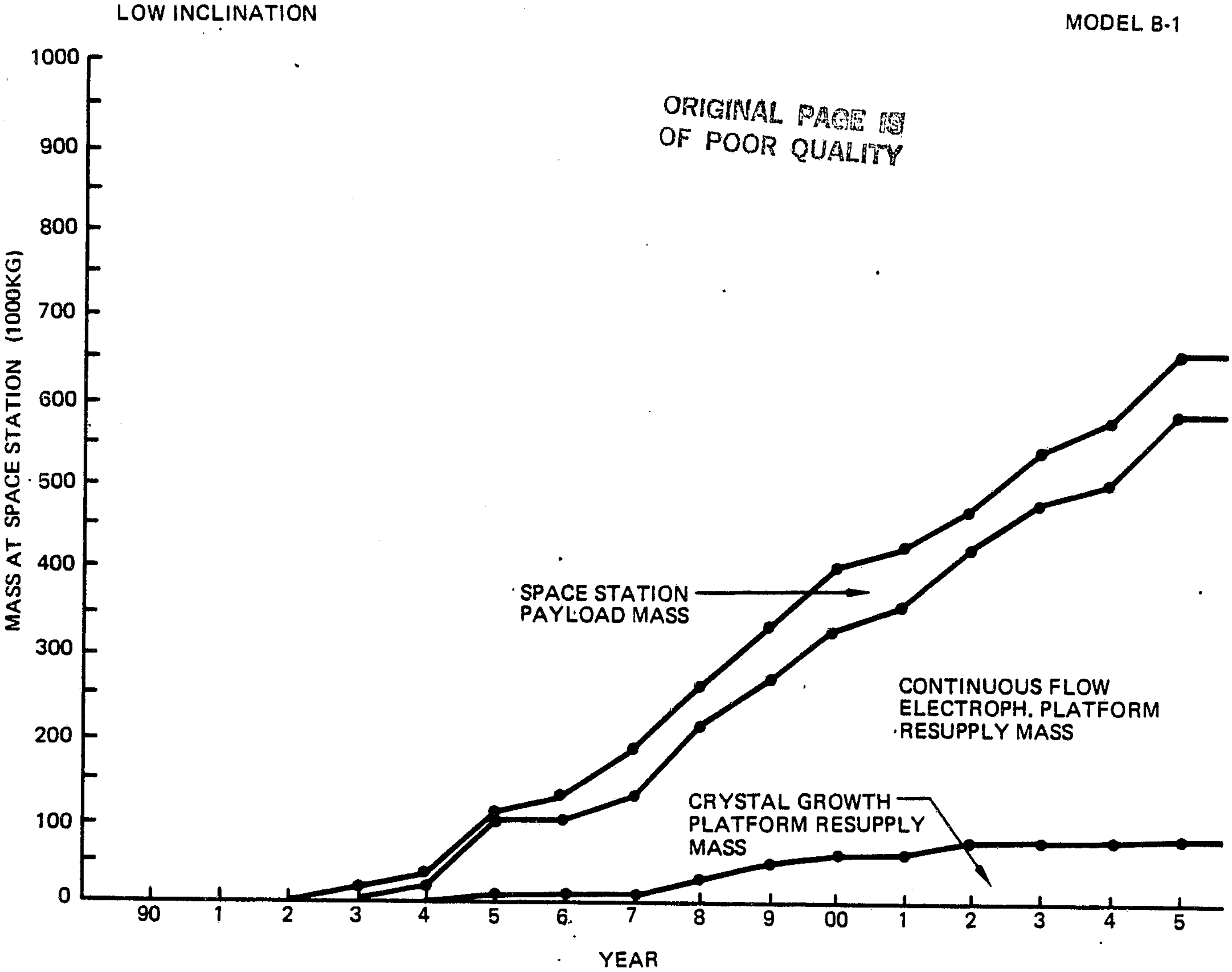

Figure 5.3-5. Low Inclination Mission Accommodation Requirements (Scenario B — Station Driven)

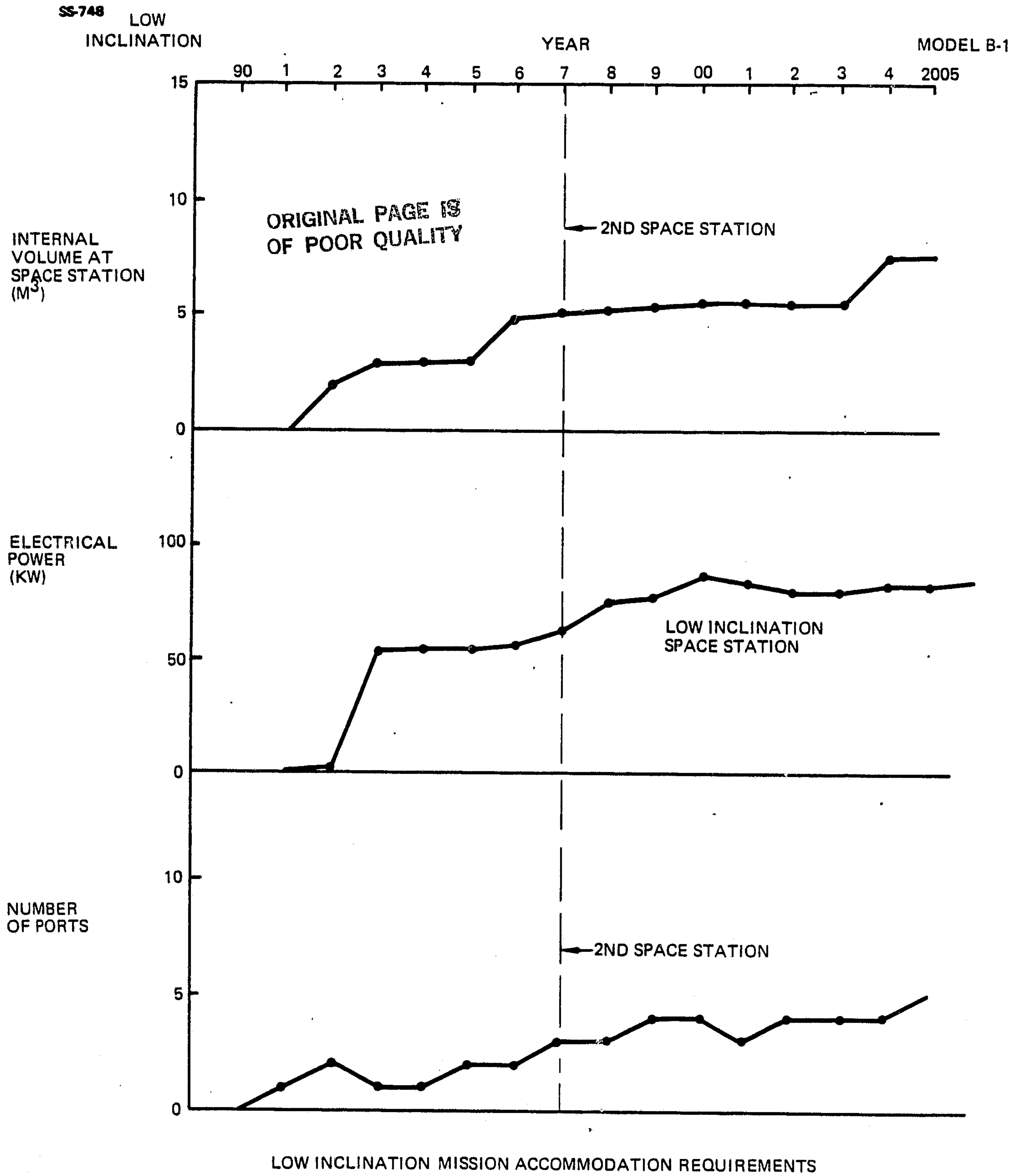

Figure 5.3-5. Low Inclination Mission Accommodation Requirements (Scenario B – Station Driven) Cont'd

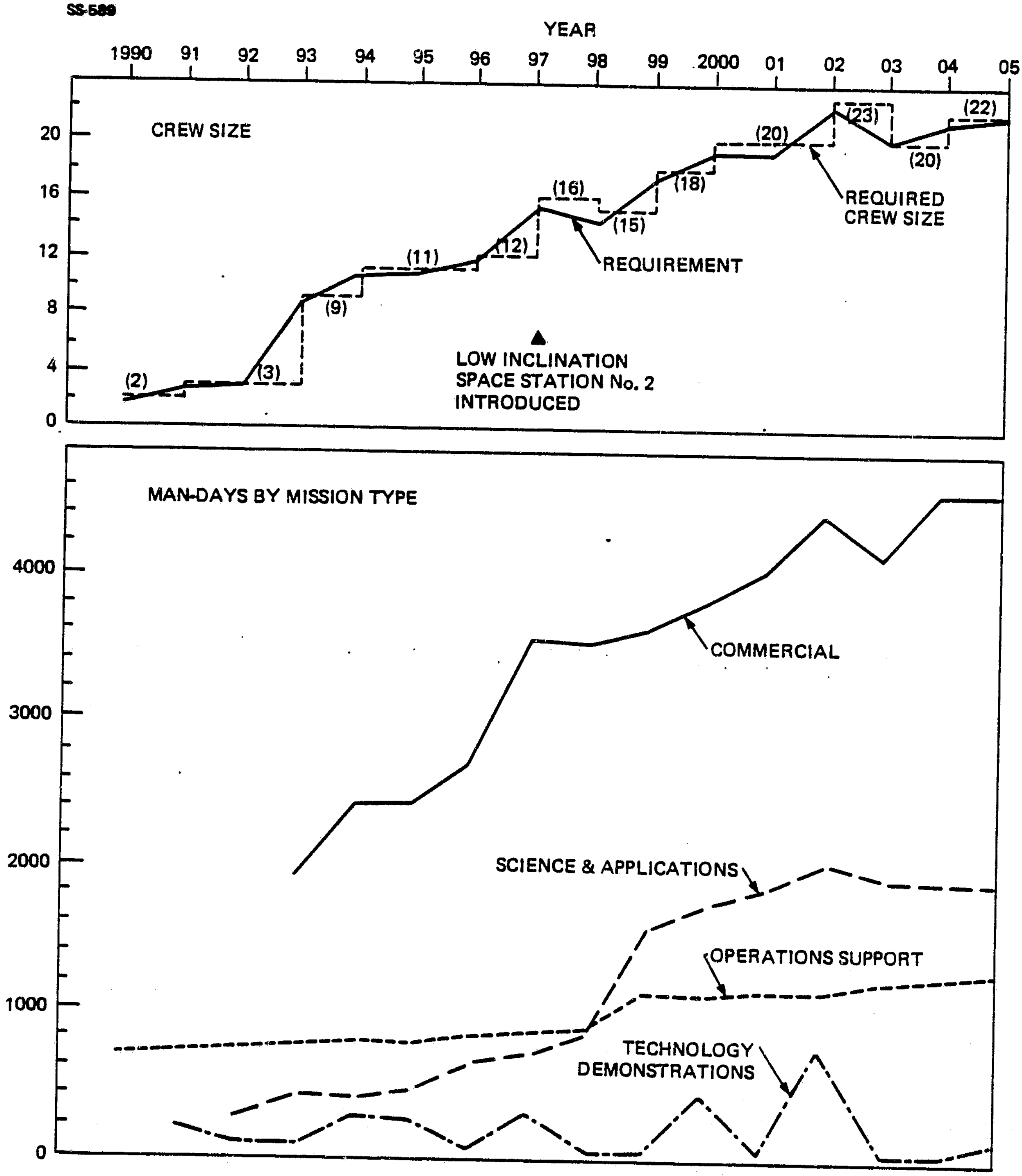

Figure 5.3-6. Low Inclination Space Station Crew Size and Operations (Scenario B-Station Driven)

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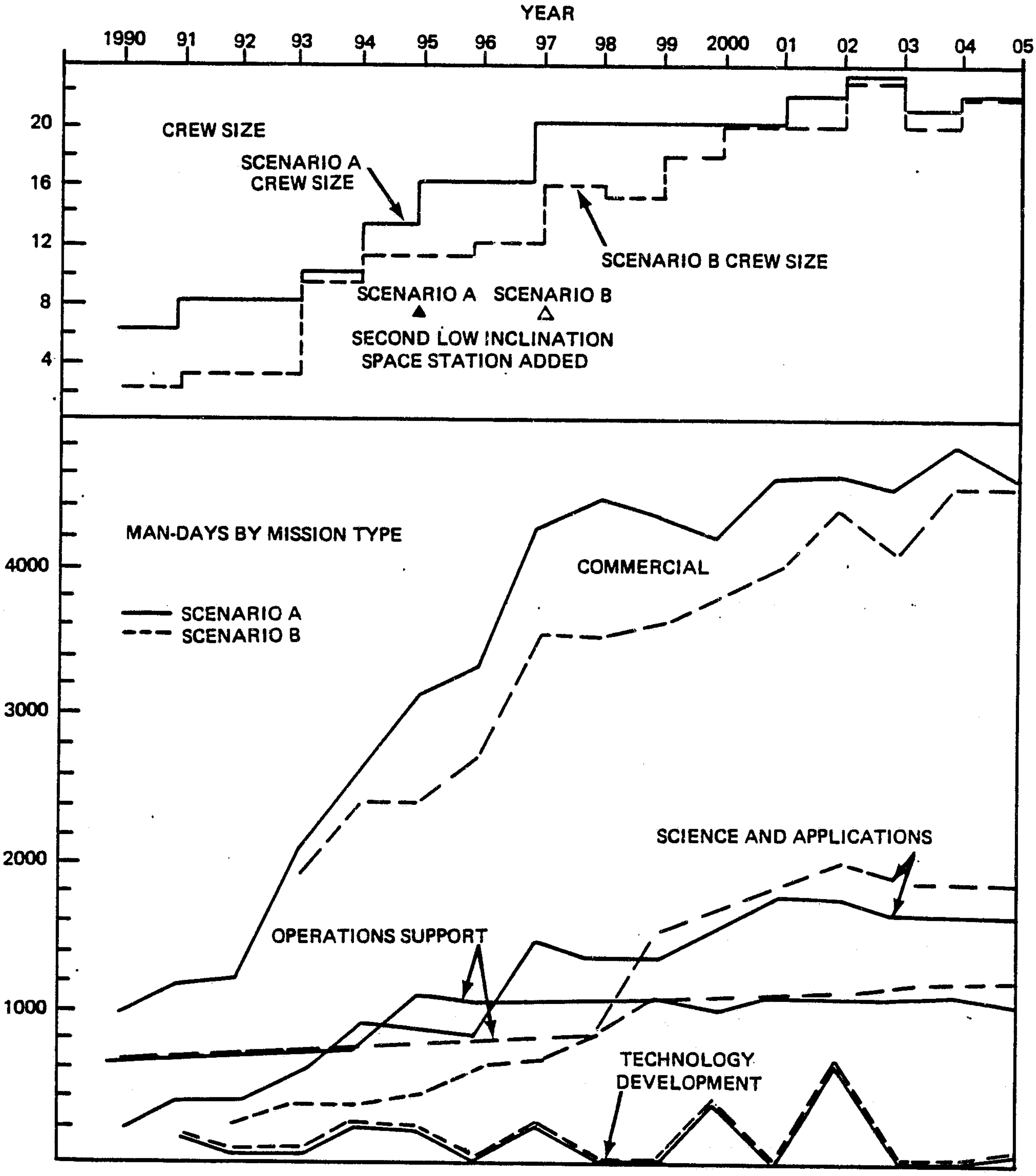

Figure 5.3-7. Comparison of Scenarios A and B Low Inclination Space Stations

5.3.2 High Inclination Space Station

5.3.2.1 Traffic Model Results

The high inclination traffic in the space station driven scenario is shown in Figure 5.3-8. The time-phased traffic profiles in this case are very similar to those in the mission-driven scenario, but four years later. This is because the high inclination missions are science-related and therefore NASA budget-constrained. The shuttle traffic starts in 1995 instead of in 1991 and the number of shuttle flights per year peaks in 1997 instead of 1993. The peak is a little higher because of a backlog of science missions. Beyond 2000 there is very little difference in the traffic.

5.3.2.2 Resource Requirements

The high inclination space station driven Scenario B yields the resource, mission accommodation requirements as shown in Figure 5.3-9. The accommodation requirements are shown in terms of (1) internal (pressurized) volume required, (2) mass at the space station, (3) electrical power required by the experiments and operations and the number of berthing ports required. The internal volume requirements are quite constant at approximately 7 m^3. The mass at the space station increase at year 1997 is accounted for by the addition of two experiment packages and the initiation of resupply to a commercial processing platform. The peak drops back down by the removal of two experiments in year 2001. Electrical power requirements are quite modest and the number of berthing ports are nearly constant at five.

5.3.2.3 Crew Activities

Figure 5.3-10 shows the time-phased crew size requirements for the Scenario B, High Inclination Space Station. It is seen that a crew of 2 is present during the first year of operation (1995). It isn't until 1996 that the station is equipped to handle missions. A crew of 3 will suffice in 1996. A crew of 4 is sufficient to handle the science and applications mission operations for the remainder of the scenario.

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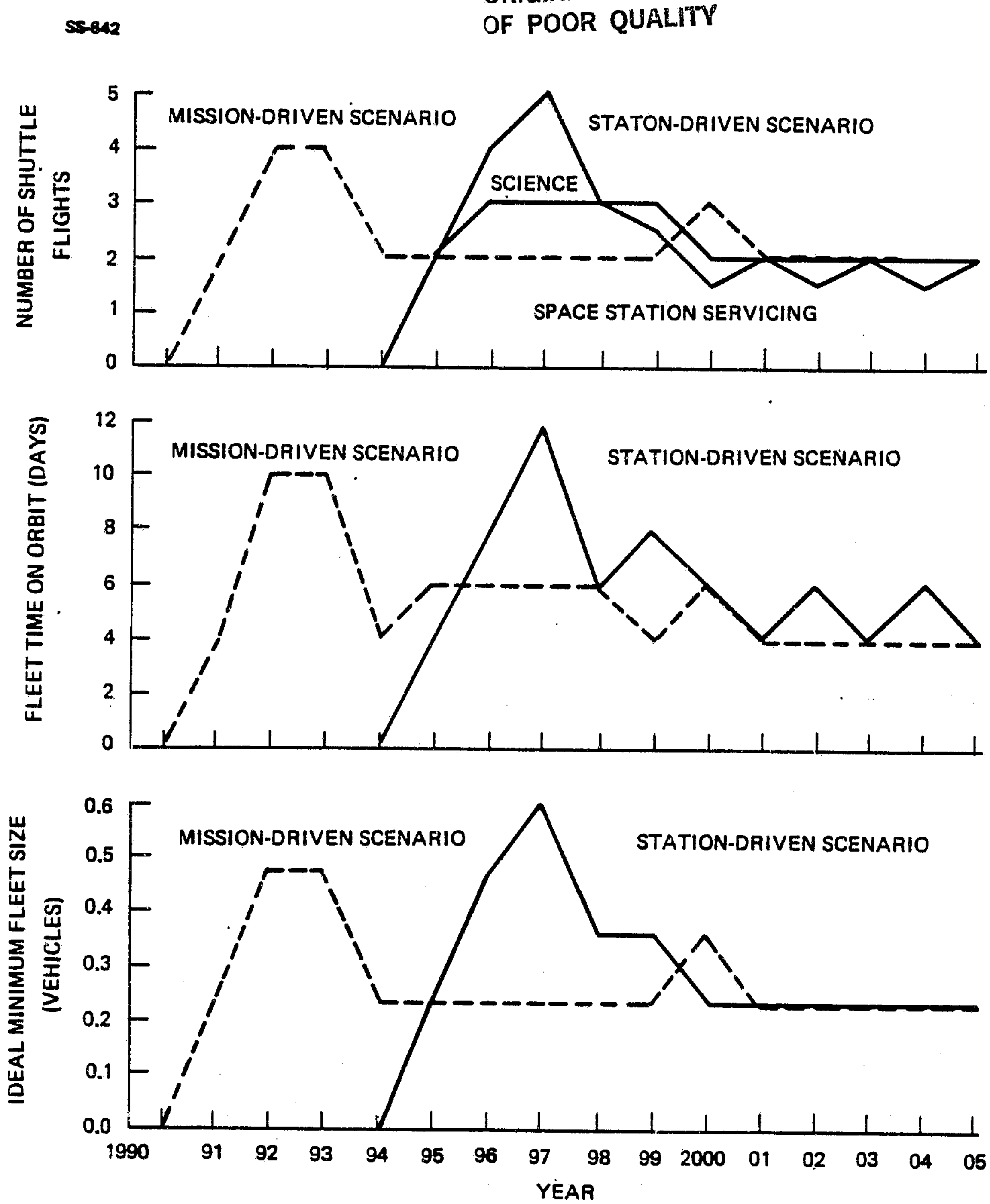

Figure 5.3-8. High Inclination Traffic in Space Station-Driven Scenario

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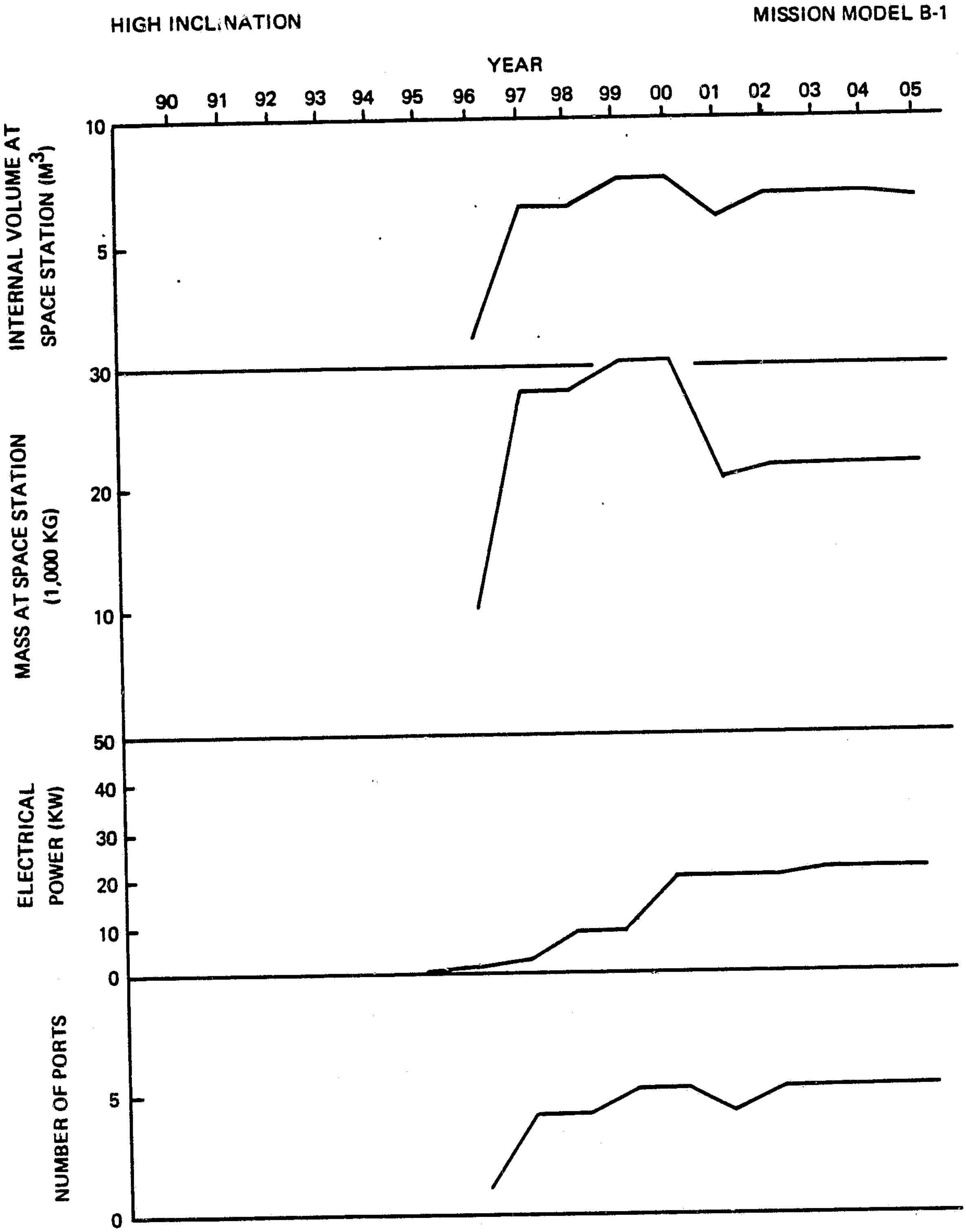

Figure 5.3-9. High Inclination Mission Accommodation Requirements (Scenario B – Station Driven)

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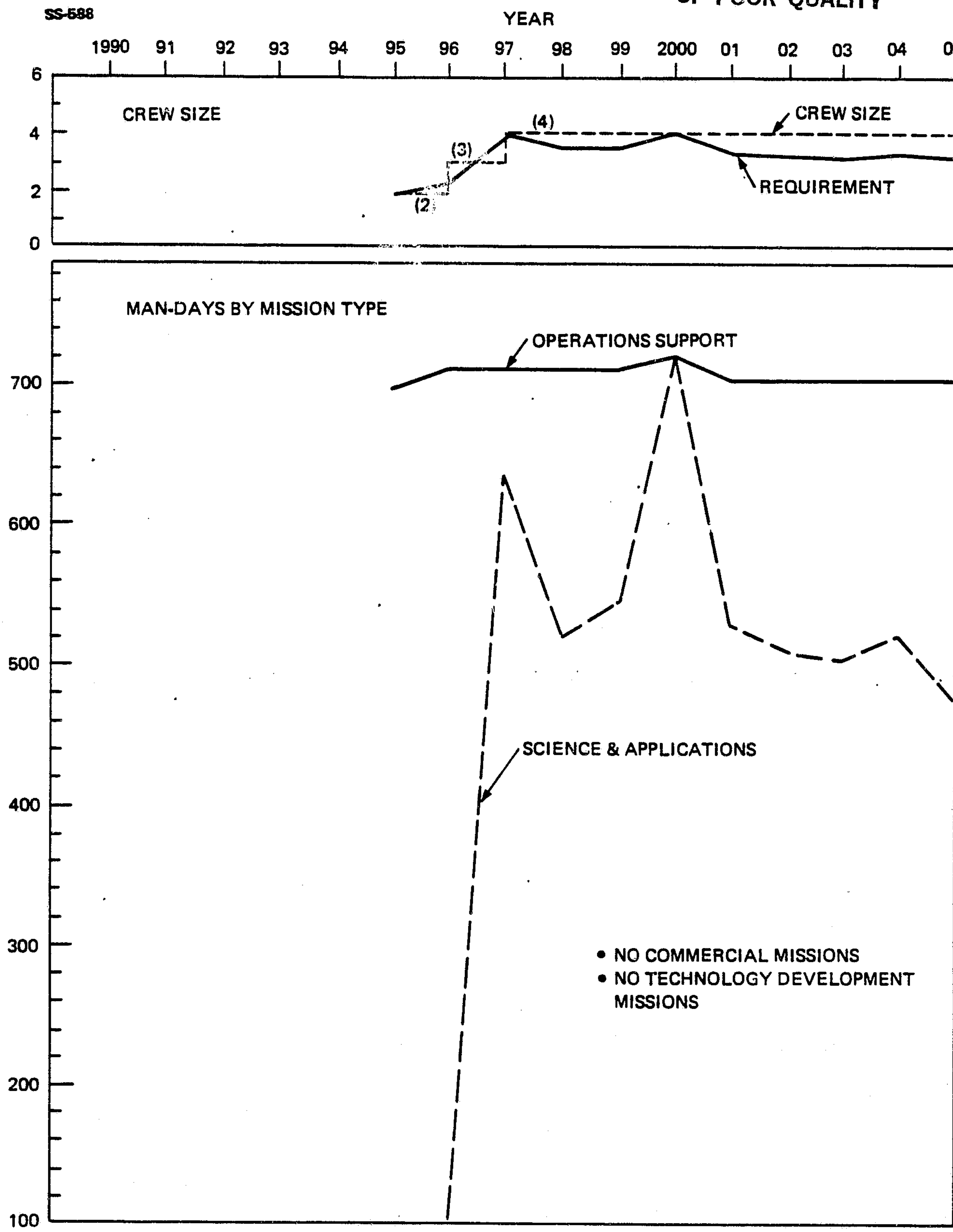

Figure 5.3-10. High Inclination Space Station Crew Size and Operations (Scenario B-Station Driven)

5.4 SCENARIO C - UNMANNED PLATFORM SCENARIO SUMMARY OF MISSION REQUIREMENTS

This scenario describes the situation where no manned space station is built. The mission scheduling is the same as it is for the mission driven scenario except for those missions which cannot be performed without a station. Commercial materials processing and communications satellite servicing are performed on a large, unmanned platform. Science instruments are attached to the platform and serviced during routine servicing revisits. Some extended life sciences mission cannot be manifested and of course, no space station modules are manifested.

5.4.1 Low Inclination Unmanned Platform

5.4.1.1 Manifesting

The manifesting model for the low inclination unmanned platform is summarized in Figure 5.4-1.

5.4.1.2 Traffic Model Results

The traffic model results are shown in Figure 5.4-2. The total number of shuttle flights grows more rapidly than in the mission-driven case. This scenario requires about 8-12 additional shuttle flights per year for servicing of materials processing free-flyers and communications and scientific satellites.

This increase in shuttle flights, although significant, is not such a dramatic effect as the increase in fleet time on orbit. The unmanned platform scenario requires up to 645 days of fleet time on orbit—implying two Orbiters actually in space most of the time. The required fleet time in space is 5-6 times as much as in the mission-driven space station scenario. This scenario involves an additional 2-3 shuttles.

Figure 5.4-3 illustrates the space-based traffic for the no space station case. Without a space station there is no space-based TMS. Commercial communications satellites still require an OTV however. Two OTV flights per year are required in 1991. The reuse rate grows to a peak of nine flights per year.

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FLIGHT SUPPORT TRAFFIC MODEL

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	C	1	2	3	4	5
18	CM02	CRYSTAL GROWTH FACTORY/PLAT	0	C	0	1	0	1	0	1	C	1	C	1	0	1	C	C
19	CM03	CRYSTAL GROWTH RESUP-1	0	C	0	0	3	3	3	C	C	0	C	C	0	C	C	0
20	CM04	CRYSTAL GROWTH RESUP-2	0	C	0	0	0	0	0	3	4	5	5	6	6	6	6	6
21	SA02	ASTRO TELESCOPE CLUSTER	0	1	0	0	C	0	-1	C	1	C	C	C	C	-1	C	C
22	SA03	ASTROPHYSICS FREE-FLYER	0	C	0	1	C	0	0	C	-1	C	C	1	C	C	C	C
23	SA04	ASTROPHYSICS OBSERVATORIES	1	C	C	0	0	0	0	C	C	C	C	C	C	C	C	C
27	CC04	MULTIBEAM COMP. SATELLITE	C	C	0	C	0	1	1	1	1	C	C	1	1	C	1	1
29	CM05	CONT FLOW ELEC-TROPH PLATFORM	1	C	0	1	C	0	1	C	C	C	1	C	0	C	C	C
30	CM06	CONTINUOUS FLOW ELECTRC RESUPP	1	4	4	5	7	9	11	12	14	16	17	2C	2C	2C	2C	2C
31	CM07	GLASS PROC PLANT	0	C	1	0	0	0	1	C	C	C	1	C	C	1	C	C
32	CM08	GLASSPROC OPTICAL FIBERS RESUPP	1	1	2	2	2	3	3	4	5	6	8	10	12	15	15	15
37	TP01	PROP TRANSFER & STORAGE	0	C	1	-1	C	0	0	C	C	0	C	C	C	C	C	C
38	TP02	OTV MAINT TECH DEMOS	C	C	C	1	-1	0	0	C	C	C	C	C	C	C	C	C
39	TS01	SATELLITE ASSY & SERVICE	0	C	0	C	1	-1	0	C	C	C	C	C	C	C	C	C
40	TE01	LARGE POWER SYS TECHNOLOGY	0	C	0	C	0	1	-1	C	C	C	C	C	C	C	C	C

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.4-1. Low Inclination Unmanned Platform Mission Manifest Schedule (Scenario C—Mission Driven)

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NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
42	TM02	PRECISION OPT CONSTR & TEST	0	0	0	0	0	0	0	0	0	0	1	-1	0	0	0	0
43	TM03	PASSIVE MICW RADIOMETER	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	0	0
44	TE02	LIQ DROPLET RADIATOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
46	SA05	LARGE RADIO TELESCOPE	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
47	SP02	CONSTRUCTION REVISIT	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
50	CC04	CONSTRUCTION REVISIT	0	0	0	0	0	1	1	1	1	0	0	1	1	0	1	1
51	CC05	CONSTRUCTION REVISIT	0	-3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
52	CM08	CONSTRUCTION REVISIT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
54	TC01	CONSTRUCTION REVISIT	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
55	TM02	CONSTRUCTION REVISIT	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
56	TM03	CONSTRUCTION REVISIT	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
57	SA05	CONSTRUCTION REVISIT	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
58	SO01	SERVICING REVISIT	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
59	SO02	SERVICING REVISIT	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
60	SO03	SERVICING REVISIT	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2
61	SO04	SERVICING REVISIT	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2
62	SP02	SERVICING REVISIT	0	0	0	2	2	2	2	0	0	0	2	2	2	2	2	2
63	SA01	SERVICING REVISIT	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2
64	CM02	SERVICING REVISIT	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2
65	SA02	SERVICING REVISIT	0	4	4	4	4	4	0	0	4	4	4	4	4	0	0	0
66	SA03	SERVICING	0	0	0	1	1	1	1	1	0	0	0	1	1	1	1	1

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.4-1. Low Inclination Unmanned Platform Mission Manifest Schedule (Scenario C—Mission Driven) (Continued)

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REVISIT

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
67	SA04	SERVICING REVISIT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
68	CM05	SERVICING REVISIT	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
69	CM07	SERVICING REVISIT	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2
70	TP02	SERVICING REVISIT	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
71	TS01	SERVICING REVISIT	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
72	TE01	SERVICING REVISIT	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
73	TM02	SERVICING REVISIT	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
74	SA05	SERVICING REVISIT	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1

TRAFFIC MODEL YEAR

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.4-1. Low Inclination Unmanned Platform Mission Manifest Schedule (Scenario C—Mission Driven) (Continued)

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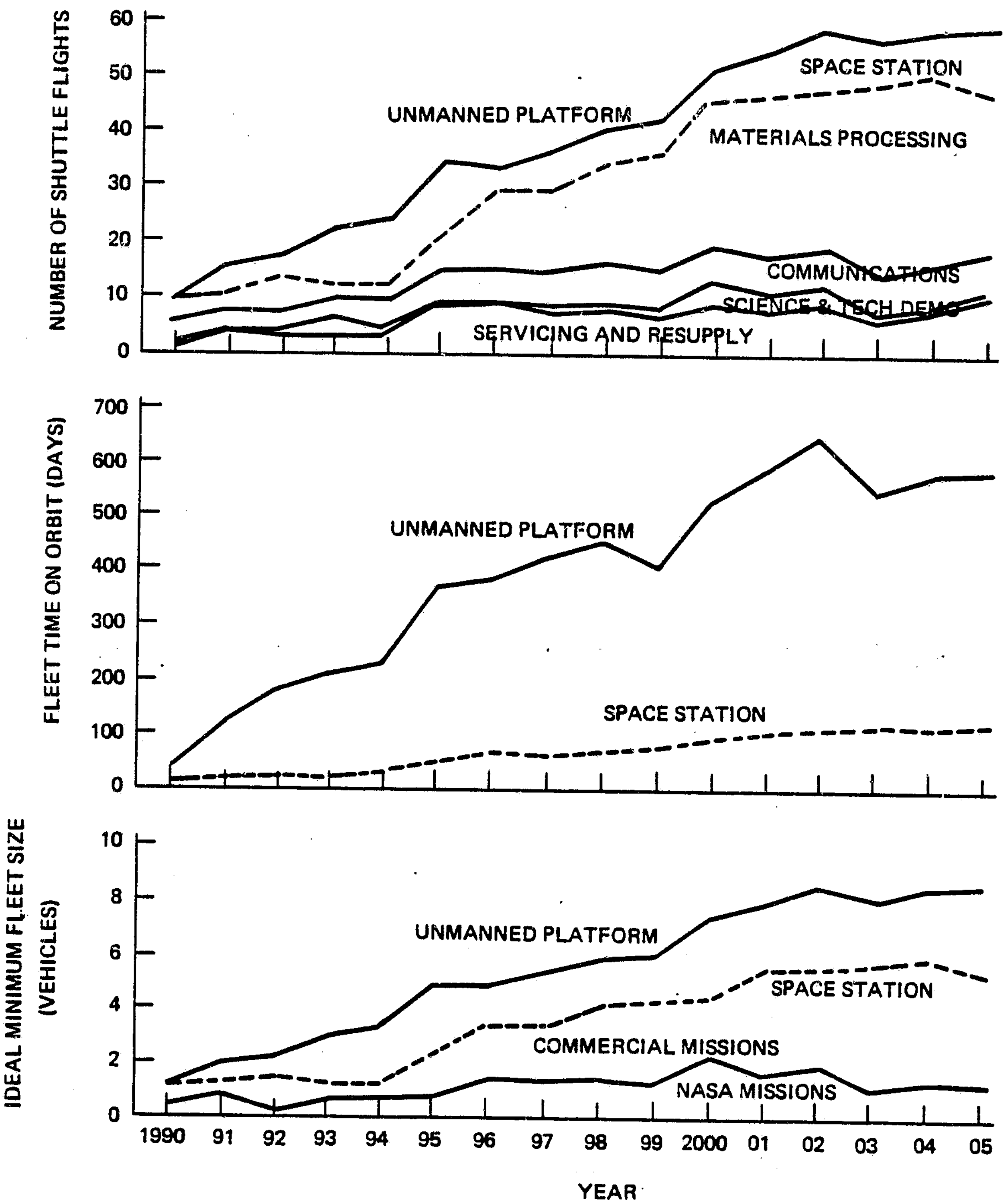

Figure 5.4-2 Low Inclination Traffic in Unmanned Platform Scenario

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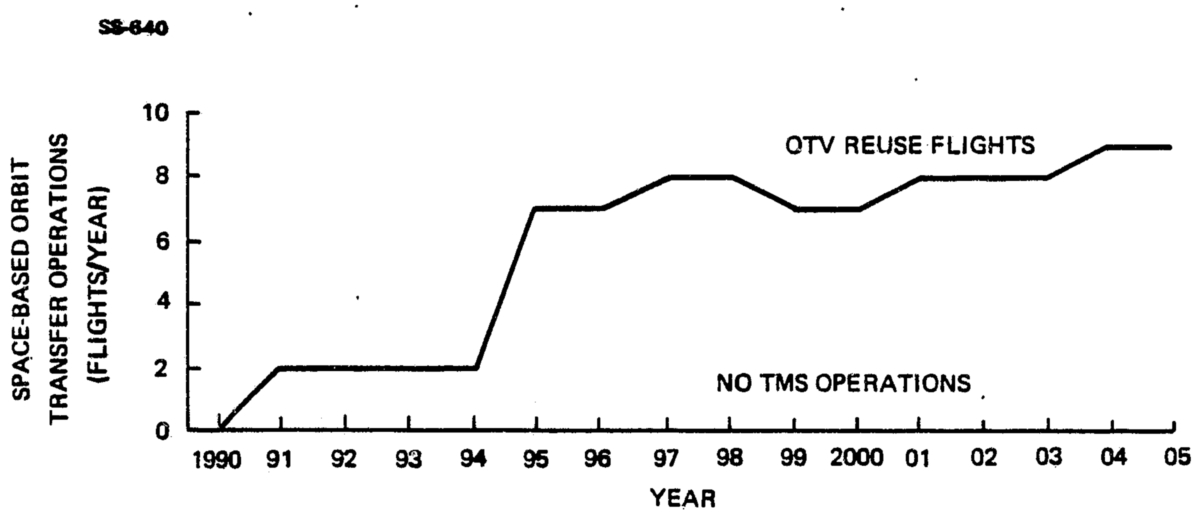

Figure 5.4-3. Space-Based Orbit Transfer Operations — No Space Station Model (Scenario C)

5.4.2 High Inclination Unmanned Platform

5.4.2.1 Introduction

The high inclination manned platform mission scenario was developed with the scientific packages launched to an unmanned platform according to the schedule shown in Figure 5.4-4. Each package requires two servicing revisits per year to provide the same operational capabilities that a manned space station would provide. Many of these revisit missions can be co-manifested, but launch mass and time-on-orbit limitations constrain this option. A comparison of the cost benefits of an unmounted platform to a space station is given in Section 6.4.

5.4.2.2 Manifesting

The manifesting model for the high inclination unmanned platform is summarized in Figure 5.4-4.

5.4.2.3 Traffic Model Results

The traffic model results are shown in Figure 5.4-5. The case with no space station requires about twice as many shuttle flights per year as the space station case, primarily for servicing. Unmanned platform missions start a year later than space station construction, so the startup costs would be lower. After 1992, however, the impact of operation without a space station is vividly seen in the fleet time on orbit, and thereby in the ideal minimum fleet size. Whereas the space station case requires an average of 5.4 days per year of fleet time on orbit after 1992, the unmanned platform case requires an average of 62.8 days per year for the same period. This much time on orbit, primarily for servicing the same payloads, may well drive the platform toward a de facto manned space station. The additional fleet time on orbit also results in an increased ideal fleet size, from 0.25 vehicles to 0.80 vehicles after 1994.

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FLIGHT SUPPORT TRAFFIC MODEL

NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
1	S001	EARTH OBSERV PALLET	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	S002	SYNTH APERTURE RADAR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3	S003	HETERODYNING CO2 LIDAR	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
4	S004	UPPER ATMOS RESEARCH PKG	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
6	ST04	HI-INCL STATION RESUPPLY	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2
7	SP01	SPACE SCIENCE SUBSATELLITE	0	0	1	0	-1	0	1	0	0	-1	0	0	0	0	0	0
8	SP02	SPACE PHYSICS PALLET	0	0	0	1	0	0	0	-1	0	0	1	0	0	0	0	0
9	SA01	VLBI/COSMIC RAY PKG	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10	SL08	RAD BIOLOGY IN SM MAMMALS	0	0	0	0	0	0	0	1	0	0	-1	0	0	1	0	0
11	SL01	HUMAN LIFE SI CARRY-ONS	0	1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
12	SL02	SMALL MAMMALS CARRY-ONS	0	1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
13	SL03	PLANT DEVEL CARRY-ONS	0	0	1	0	0	0	0	-1	0	0	0	0	0	0	0	0
18	CM02	CRYSTAL GROWTH FACTORY/PLAT	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	0
19	CM03	CRYSTAL GROWTH RESUP-1	0	0	0	0	3	3	3	0	0	0	0	0	0	0	0	0
20	CM04	CRYSTAL GROWTH RESUP-2	0	0	0	0	0	0	0	2	4	5	5	6	6	6	6	6

(Column years 90–5: TRAFFIC MODEL YEAR)

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.4-4. High Inclination Unmanned Platform Mission Manifest Schedule Scenario C — Mission Driven

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NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5
			TRAFFIC MODEL YEAR															
21	SA02	ASTRO TELESCOPE CLUSTER	0	1	0	0	0	0	-1	0	1	0	0	0	0	-1	0	0
22	SA03	ASTROPHYSICS FREE-FLYER	0	0	0	1	0	0	0	0	-1	0	0	1	0	0	0	0
23	SA04	ASTROPHYSICS OBSERVATORIES	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	CC01	SUSS-CLASS COMSAT	6	6	6	6	8	8	8	8	8	8	8	8	8	8	8	8
25	CC02	INTELSAT-6A CLASS COMSAT	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
26	CC03	INTELSAT-7,7A CLASS COMSAT	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2
27	CC04	MULTIBEAM COMM. SATELLITE	0	0	0	0	0	1	1	1	1	0	0	1	1	0	1	1
28	CC05	RECONFIGURABLE COMM. SATELLITE	0	1	1	1	1	2	3	4	4	4	4	4	4	4	4	4
29	CM05	CONT FLOW ELEC-TROPH PLATFORM	1	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0
30	CM06	CONTINUOUS FLOW ELECTRO RESUPP	1	4	4	5	7	9	11	12	14	16	17	20	20	20	20	20
31	CM07	GLASS PROC PLANT	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0
32	CM08	GLASSPROC OPTICAL FIBERS RESUPP	1	1	2	2	2	3	3	4	5	6	8	10	12	15	15	15
33	OT01	LOW INCL STA MODULE DEL	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
34	OT02	LOW INCL STA RESUPPLY	0	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4
35	OT05	HI ALT STA RESUPPLY	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2
37	TP01	PROP TRANSFER & STORAGE	0	0	1	-1	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.4-4. High Inclination Unmanned Platform Mission Manifest Schedule Scenario C – Mission Driven (Continued)

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NO. KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	C	1	2	3	4	5
		TRAFFIC MODEL YEAR															
38 TP02	OTV MAINT TECH DEMOS	0	C	C	1	-1	0	0	C	C	C	C	C	C	C	C	C
39 TS01	SATELLITE ASSY & SERVICE	0	C	0	C	1	-1	0	C	C	0	C	C	C	C	C	C
40 TE01	LARGE POWER SYS TECHNOLOGY	0	C	0	0	0	1	-1	C	C	0	C	C	C	C	C	C
41 TC01	ROBOTICS TECH DEMO	0	C	0	0	C	0	0	1	-1	0	C	C	C	C	C	0
42 TM02	PRECISION OPT CONSTR & TEST	0	C	0	0	C	0	0	C	C	C	1	-1	C	C	C	C
43 TM03	PASSIVE MICW RADIOMETER	0	C	0	0	C	0	0	C	C	0	C	0	1	-1	C	C
44 TE02	LIQ DROPLET RADIATOR	0	C	0	0	0	0	0	C	C	C	C	C	C	C	C	1
45 TS01	TECH DEVEL CARRY-ONS	C	1	C	0	0	0	0	C	C	C	C	C	C	C	C	C
46 SA05	LARGE RADIO TELESCOPE	C	C	0	C	C	0	0	C	C	C	1	C	C	C	C	C
47 SP02	CONSTRUCTION REVISIT	0	C	0	1	0	0	0	C	C	C	1	C	C	C	C	C
50 CC04	CONSTRUCTION REVISIT	0	C	0	C	0	1	1	1	1	C	C	1	1	C	1	1
51 CC05	CONSTRUCTION REVISIT	C	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
52 CM08	CONSTRUCTION REVISIT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
54 TC01	CONSTRUCTION REVISIT	0	C	C	0	C	0	0	1	C	C	C	C	C	C	C	C
55 TM02	CONSTRUCTION REVISIT	0	C	0	C	C	0	0	C	C	C	4	C	C	C	C	C
56 TM03	CONSTRUCTION REVISIT	0	C	0	0	C	0	0	C	C	C	C	0	4	0	C	C

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.4-4. High Inclination Unmanned Platform Mission Manifest Schedule Scenario C – Mission Driven (Continued)

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NO.	KEY	PAYLOAD DESCRIPTION	90	91	92	93	94	95	96	97	98	99	C	1	2	3	4	5
									TRAFFIC MODEL YEAR									
57	SA05	CONSTRUCTION REVISIT	0	C	0	C	C	0	0	C	C	C	3	C	C	C	C	C
58	S001	SERVICING REVISIT	C	C	0	1	1	1	1	1	1	1	1	1	1	1	1	1
59	S002	SERVICING REVISIT	0	C	0	0	0	1	1	1	1	1	1	1	1	1	1	1
60	S003	SERVICING REVISIT	0	C	0	0	C	0	0	C	2	2	2	2	2	2	2	2
61	S004	SERVICING REVISIT	C	C	C	C	C	0	0	2	2	2	2	2	2	2	2	2
62	SP02	SERVICING REVISIT	C	C	0	2	2	2	2	C	C	C	2	2	2	2	2	2
63	SA01	SERVICING REVISIT	C	C	2	2	2	2	2	2	2	2	2	2	2	2	2	2
64	CM02	SERVICING REVISIT	0	C	0	2	2	2	2	2	2	2	2	2	2	2	2	2
65	SA02	SERVICING REVISIT	0	4	4	4	4	4	0	C	4	4	4	4	4	C	C	C
66	SA03	SERVICING REVISIT	C	C	0	1	1	1	1	1	C	C	C	1	1	1	1	1
67	SA04	SERVICING REVISIT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
68	CM05	SERVICING REVISIT	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
69	CM07	SERVICING REVISIT	C	C	2	2	2	2	2	2	2	2	2	2	2	2	2	2
70	TP02	SERVICING REVISIT	C	C	C	1	C	0	C	C	C	C	C	C	C	C	C	C
71	TS01	SERVICING REVISIT	C	C	0	C	1	0	0	C	C	C	C	C	C	C	C	C
72	TE01	SERVICING REVISIT	C	C	C	0	C	1	0	C	C	C	C	C	C	C	C	C
73	TM02	SERVICING REVISIT	C	C	0	0	0	0	0	C	C	C	1	C	C	C	C	C
74	SA05	SERVICING REVISIT	C	C	C	C	C	0	0	C	C	C	1	1	1	1	1	1

NOTE:
PAYLOAD CHARACTERISTICS ARE FOUND IN APPENDIX 4

Figure 5.4-4. High Inclination Unmanned Platform Mission Manifest Schedule Scenario C – Mission Driven (Continued)

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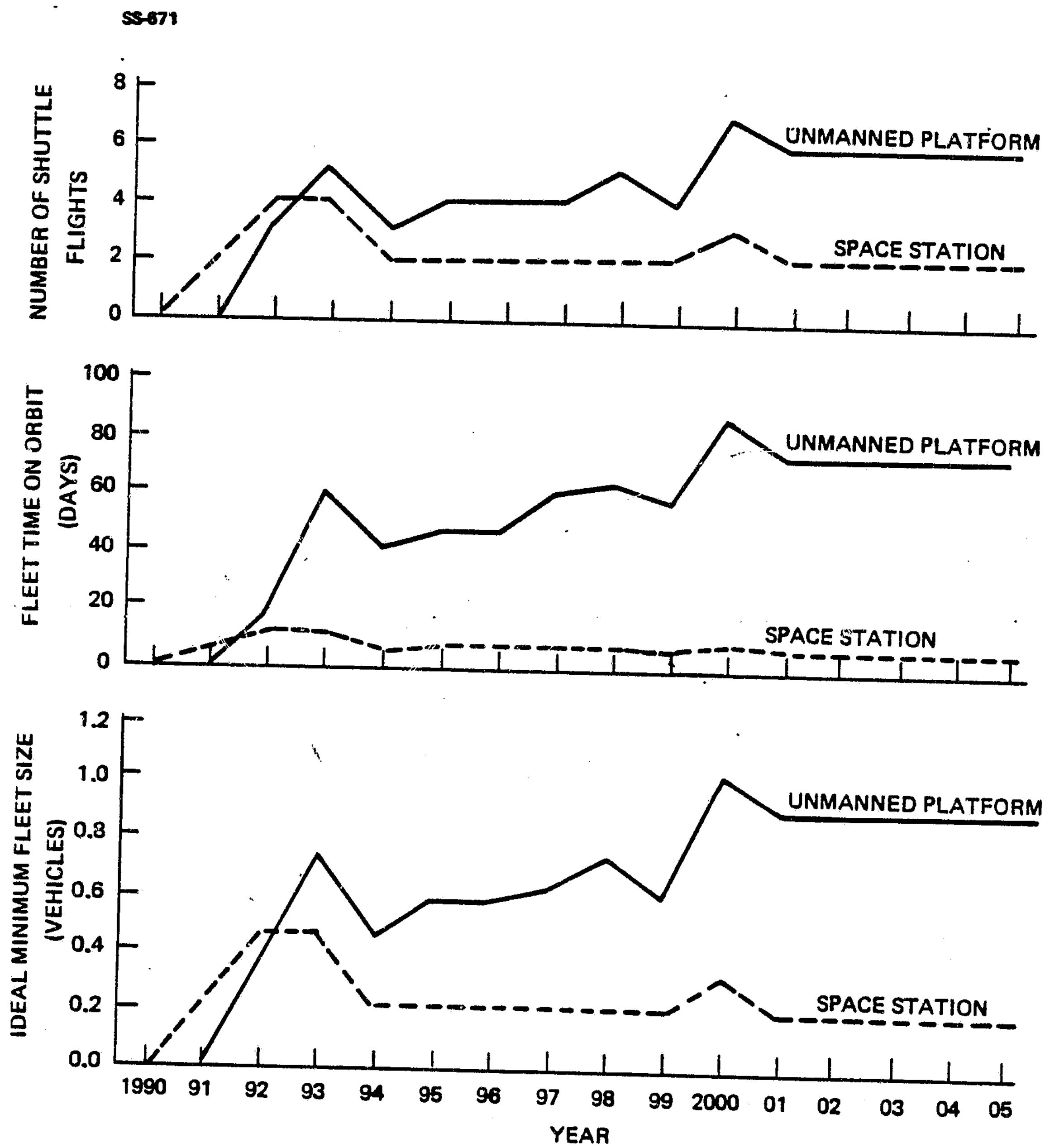

Figure 5.4-5. High Inclination Traffic Model with Unmanned Platform Only

6.0 BENEFITS ANALYSIS

6.1 INTRODUCTION

The Space Station specific cost-benefit analyses were conducted on a high inclination space station, space production of GaAs crystals, and DBS (Direct Broadcast Satellite) systems. All these studies compare two scenarios—one with Shuttle only and the other with Shuttle plus Space Station. The studies assume that the services rendered or products produced are identical and, therefore, the gross benefits derived in either scenario are the same. The difference in the two scenarios comes through the difference in the cost incurred in providing the services or product. So, the net benefit derived is the difference in the cost of providing the services or products in the two scenarios.

The net benefit calculation first involved finding the year by year costs under the two scenarios under consideration for each case (GaAs production, DBS, or high inclination missions). Next, these cost streams were discounted using two discount rates, 10% and 15%, to arrive at the present values of the cost streams. The cost streams for the GaAs production and high inclination missions were discounted to find their present values in 1992. In the DBS case the cost streams were discounted to arrive at their present values in 1991. The discounted year by year cost streams were added to obtain the total discounted costs for each case under the two scenarios under consideration. Finally, net benefits due to the availability of a space station is calculated by subtracting the discounted total cost without the space station scenario. If the net benefits thus calculated are positive then the availability of a space station is beneficial. On the other hand, if net benefits are negative then it is not beneficial to have a space station.

Now a few words about discount rate, discounting, and present value. In the studies below there are costs incurred over a period of time. It is of interest to obtain the total cost from these year by year costs. A simple way would be to add up the year by year costs to obtain total cost. This total is misleading since this approach does not take into account the time preference of incurring costs. Usually, it is always economically rational to incur costs in later years of a project rather than in the early years of a project. Suppose that a two-year project costs 100 dollars, and that the 100 dollars can be spent in the first year of the

project or in the second year of the project. Given an interest rate of 10%, one can take 90.9 dollars and invest it in the 1st year to obtain 100 dollars (principal and interest) at the end of the 1st year. Now, 100 dollars can be spent in the second year. If the costs are incurred in the first year then 100 dollars are needed. So, it can be seen that in order to spend 100 dollars in the second year, one need only start with about 90 dollars. Therefore, the present value at the beginning of the 1st year of the 100 dollars in the second year is 90.9 dollars. This present value of 90.9 is obtained by discounting the 100 dollars with a discount rate of 10%. This discount rate is the interest rate or the cost of borrowing money. This is the type of discounting that has been performed in the following studies in order to obtain net benefits.

6.2 SPACE PRODUCED GALLIUM ARSENIDE (GaAs) CRYSTAL

Two alternative modes of producing GaAs in space are considered here. In either case it is assumed that a Free Flyer is available. The Shuttle only case assumes that GaAs crystal producing furnaces and seed crystals will be transported on a Shuttle to the Free Flyer where it will be transferred through EVA. The furnace will then be turned on and left on until the desired amount of crystals are produced. The produced crystals will then be transported back to earth on a later flight for further processing on the ground. The Space Station case assumes that the Shuttle ferries the furnaces and seed crystals to the Space Station and these are then transferred to a Free Flyer. After the production of the desired amount of GaAs crystals are complete, the crystals are transferred to the Space Station and stored for a maximum period of 45 days before being transported back to earth on a Shuttle. The transfer of GaAs production hardware to and from the Free Flyer in this case is assumed to be conducted using a Tele-Maneuvering System (TMS).

The major difference in the production of GaAs in the two scenarios described above is the availability of power on the Free Flyer. In the Shuttle only case, the Free Flyer is power limited to 20 kW and thus only one furnace can be operated at a time. Since it is assumed that 20 kW power availability enables 20 kgs per week or 1000 kg per year of GaAs to be produced, the production of more than 1000 kg of GaAs per year requires more than one Free Flyer. On the other hand, in the Space Station case the Free Flyer is not power limited. Therefore, more than one furnace can be operated simultaneously on a Free Flyer.

The costs incurred in producing GaAs in the two scenarios are summarized in Table 6.2-1. The Shuttle Free Flyer case incurs two major types of costs—STS related costs and Free Flyer related costs. STS related costs are the charges for taking up the GaAs production hardware, EVA costs, and extra days on orbit costs. It is assumed that each mission to a Free Flyer includes delivery of production hardware and retrieval of already produced GaAs crystals and involves one EVA and three extra days on-orbit. The Free Flyer charges are basic charges for the usage of the Free Flyer and charges for the usage of power at the rate of 20 kW at most.

The Space Station tended Free Flyer incurs three major types of costs—STS related, Free Flyer related, and Space Station related. Free Flyer related costs incurred are the basic charges and power usage charges depending on how long the Free Flyer was in use. It should be remembered that in this case the Free Flyer is not limited to supplying 20 kW and therefore, can service more than one furnace at a time. The only STS charge is the charge for transporting the GaAs production hardware to the Space Station. Space Station related costs are incurred for the usage of Space Station berthing port, for the usage of TMS services, for storage, and for the crew-time involved. It is assumed that each Shuttle mission uses up one day at the berthing port. Also the number of days of crew-time involved in each production run is three days. Finally, it is assumed that the produced crystals are stored in the Space Station for a period of 45 days before they are transported back to earth for processing.

The cost-benefit analysis is conducted on the basis of the projected demand for space produced GaAs. Figure 6.2-1 shows the Boeing supplied projected demand for GaAs from 1992 to 2000. This study looks at the costs incurred in producing this amount in the Shuttle only case and in the Space Station case. This means that net benefit is just the difference between the costs incurred in the two scenarios. The discounted cost streams for both the scenarios and net benefit due to the availability of Space Station is summarized in Table 6.2-2. Table 6.2-2 shows that the costs incurred in producing GaAs to meet the projected demand in the Shuttle only case is more than the costs incurred in producing the same amount of GaAs with the availability of Space Station. The total net benefit** over the eight year production period is 386.96M in 1982 dollars at 10% discount rate or 298.82M in 1982 dollars at 5% discount rate.

Table 6.2-1. Costs Incurred in Producing GaAs in Space
(in 1982 dollars)

SHUTTLE TENDED FREE FLYER CASE

A. STS COSTS:

i. Transportation cost at the rate of $124M per dedicated flight or $4203 per kg.

ii. EVA costs at the rate of $186,000 per EVA.

iii. Extra days on orbit costs at $650,000 per day.

B. FREE FLYER COSTS:

i. Basic usage charge of $48M per week.

ii. Cost of power at the rate of $4,500 per kW per day.

C. --

SPACE STATION TENDED FREE FLYER CASE

A. STS COSTS:

i. Transportation cost at the rate of $124M per per dedicated flight or $4203 per kg.

B. FREE FLYER COSTS:

i. Basic usage charge of $48M per week.

ii. Cost of power at the rate of $4,500 per kW per day.

C. SPACE STATION CHARGES:

i. Berthing port charges of $3,500 per day.

ii. Storage charges of $5 per cubic foot.

iii. Crew time at the rate of $38,500 per day.

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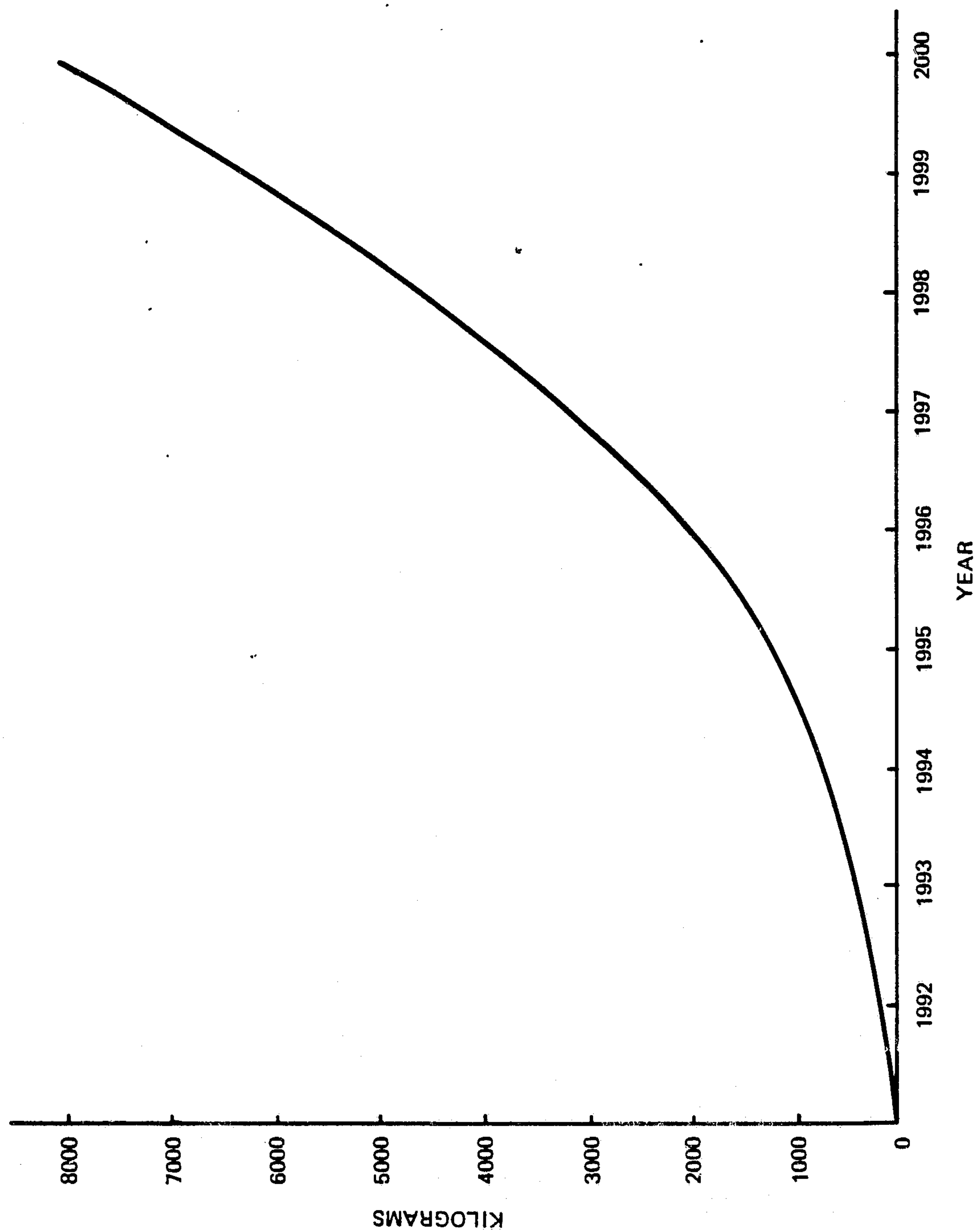

Figure 6.2-1. Projected Demand for Space Produced GaAs

Table 6.2-2. Space Station Cost-Benefit Case Study—GaAs Production

Method of Production	Discount Rate	Value of Cost Streams Discounted to 1992 (in millions of 1982 dollars)									Total Discounted Costs
		1992	1993	1994	1995	1966	1997	1998	1999	2000	
Space Station serviced Free Flyer	10%	27.08	40.98	62.09	80.81	116.22	161.94	202.81	242.59	290.94	1225.46
	15%	27.08	39.20	56.81	70.72	97.29	129.67	155.33	177.72	203.88	957.7
Shuttle serviced Free Flyer	10%	29.87	44.84	65.57	99.41	193.26	212.32	262.86	317.32	386.97	1612.42
	15%	29.87	42.89	60.01	87.00	161.78	170.00	201.32	232.47	271.18	1256.52

Net benefit due to the availability of Space Station* (at 10% discount) = 386.96M in 1982 dollars

Net benefit due to the availability of Space Station* (at 15% discount) = 298.82M in 1982 dollars

* Since both modes of production are satisfying the same amount of GaAs demanded, net benefits are the differences between production costs.

For comparison purposes, the projected revenue streams from meeting the demand in figure 6.2-1 were calculated and are shown in Figure 6.2-2 for two discount rates. The price per kg of GaAs that was used in arriving at total revenues over the eight year period was taken from a Boeing supplied projected price trend. The price trend from 1992 to 2000 is depicted in figure 6.2-3. From Figure 6.2-3 and Table 6.2-2, it can be surmized that space production of GaAs is financially viable, in both the Shuttle only case and in the Space Station case. But, it is more efficient to have the GaAs produced with a Space Station. This is reflected in the positive net benefits for the Space Station production case.

6.3 DIRECT BROADCASTING SATELLITE SYSTEMS (DBS)

A comprehensive domestic DBS system is assumed to consist of four satellites providing broadcast coverage to the four conus time zones from four orbit locations. The satellites are identical except for the feed horns and associated feed networks. Spare satellites are placed in orbit to provide coverage in case of failure of one of the operating satellites. Since a single satellite cannot house the four different horns corresponding to all the time zones, two space satellites are required to ensure continuous coverage: one spare providing backup for the Eastern and Central time zone and one for the Mountain and Pacific time zone. Each spare is equipped with two sets of switchable feed horns and their corresponding feed network. A complete domestic DBS constellation therefore requires six satellites on orbit, with at least two of them possessing a double feed horn system with switching capability.

The existence of a permanent Space Station will eliminate the requirement for one of the two spare satellites and the requirement for switchable horns. Rather than provide two satellites in orbit, it will be possible to maintain one spare satellite in storage on the Space Station. This satellite would not be equipped with feed horns and their feed networks, which would be stored separately on the platform. There would be four different feed horn network assemblies available, and the appropriate one would be installed on the spare satellite when failure of an orbiting satellite occurred. Rapid replacement of a failed satellite can thus be assured by a single satellite stored on the Space Station rather than by two satellites in orbit. This will result in saving of one complete satellite per constellation, plus the added expense associated with the switchable arrays needed for the Shuttle only

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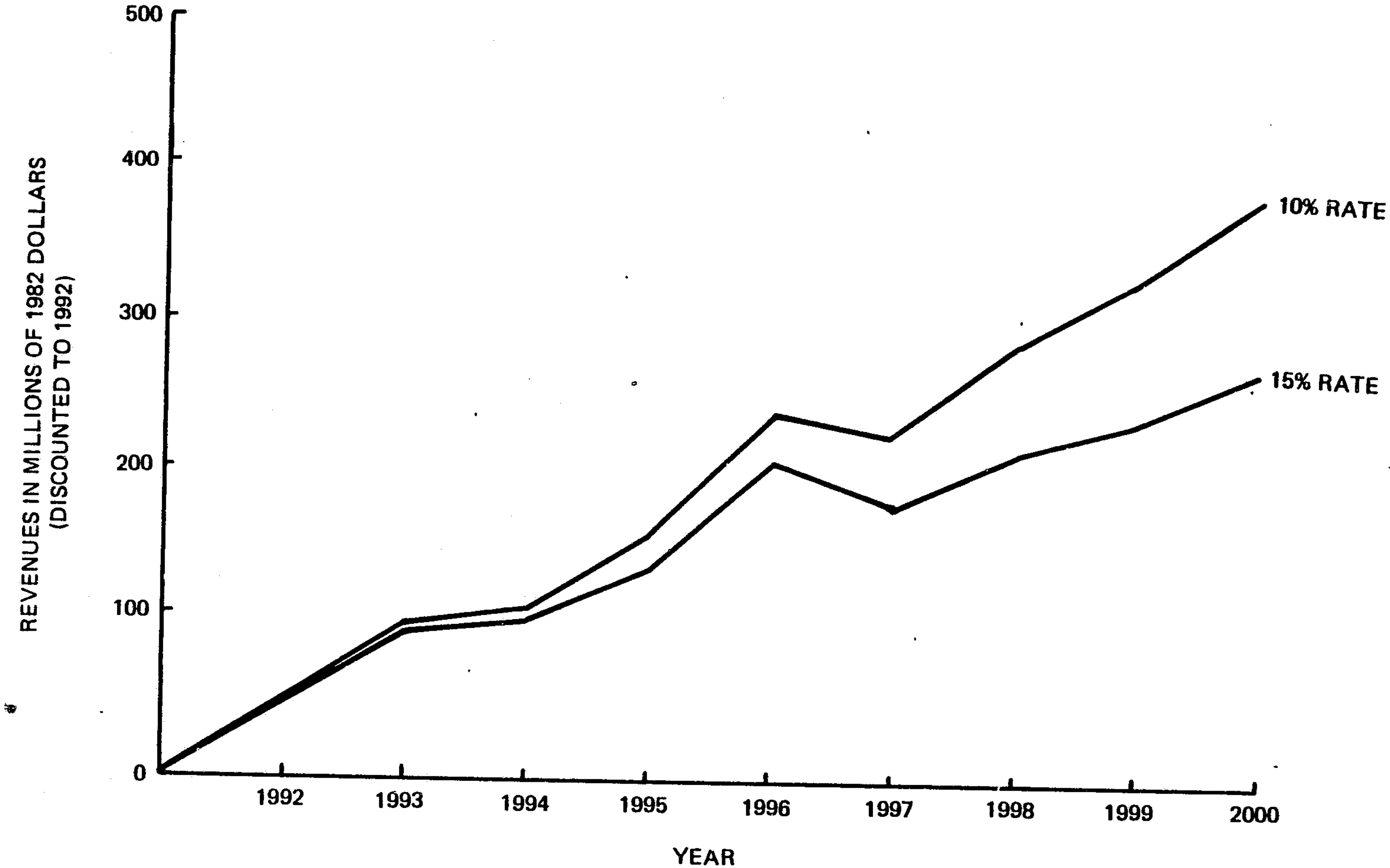

Figure 6.2-2. Projected Revenues from Space Produced GaAs

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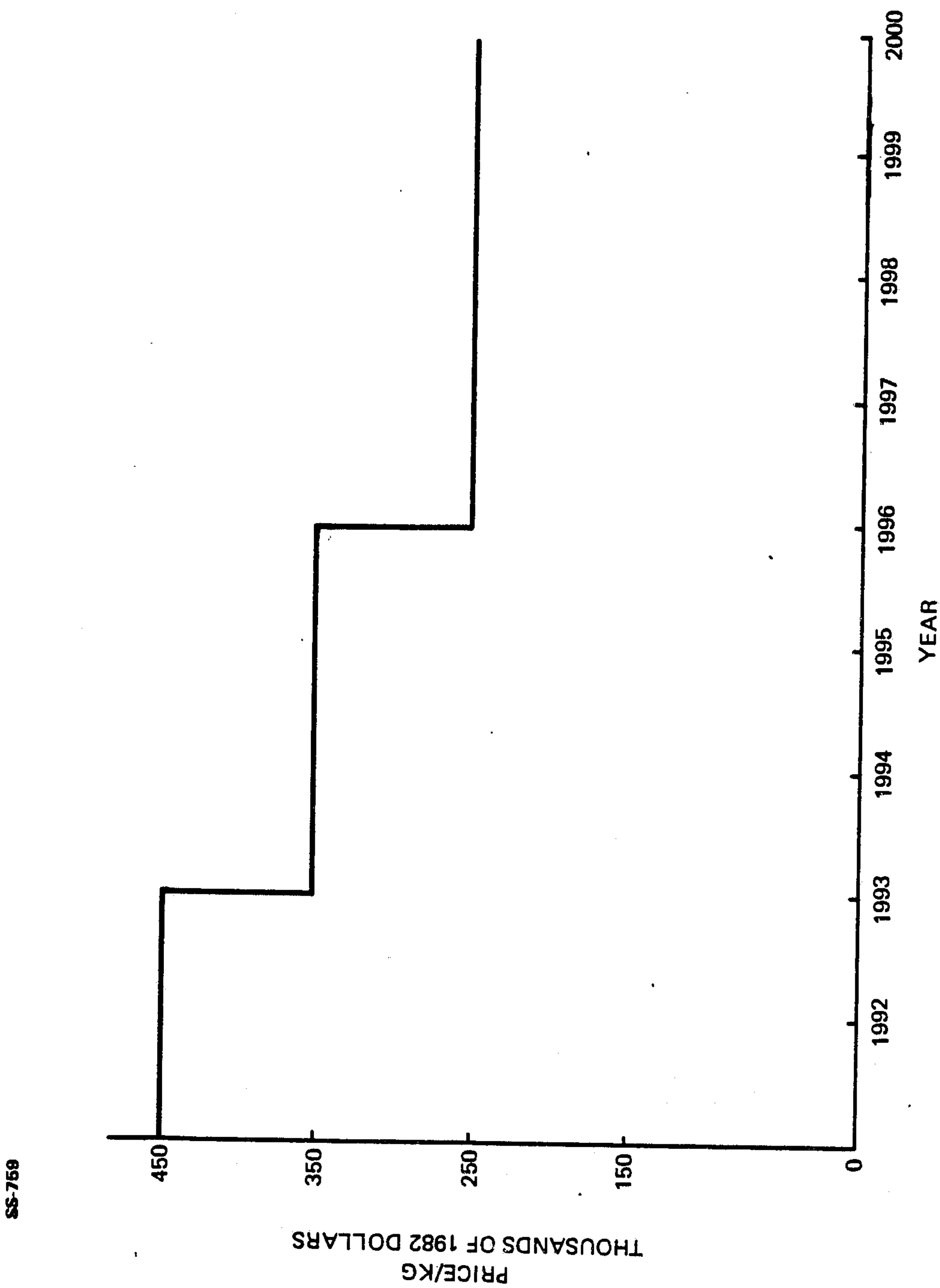

Figure 6.2-3. Projected Price of Space Produced GaAs

scenario. This saving will be offset by the charges for storage and servicing at the Space Station.

Another benefit of having a Space Station would be the possibility of extending satellite life through regular maintenance and servicing. This would mean the operation of a five-satellite DBS constellation on a regular rotation schedule, with each satellite being brought to the Space Station for refueling and refurbishing every four years. This study assumes that rotation starts from the third year from the start of the operation of a DBS system. Assuming a 10 year operational lifetime of a satellite, the total lifetime of a satellite can be increased to 12 years.

Typical costs incurred in both the scenarios are summarized in Table 6.3-1.

The Shuttle only case of deploying and operating DBS systems incurs two types of costs—launch costs and satellite costs. The launch costs include Shuttle cost and spacecraft integration cost. Satellite costs include spacecraft cost, feed horn cost and switchable system cost for the spare satellites.

Space Station availability scenario contributes to three major types of costs—launch costs, satellite costs, and reconfiguration and maintenance cost. Launch costs are the same as the Shuttle only case. For satellite costs, the spacecraft cost and feed horn costs are assumed to be the same as in the Shuttle only case, but the availability of Space Station obviates the need for switchable feed horns. The third type of costs involved with the Space Station case are reconfiguration and servicing costs. There is a one time cost of $4M per DBS system for refurbishing each satellite.

For mission traffic modeling, this study assumes that one new DBS system is introduced each year from 1991 to 1998. The period under consideration is 1991 through 2002. Thus, in the Shuttle only scenario six satellites would be launched every year starting from 1991 until all eight systems are up by the end of 1998. Assuming a 10 year satellite operational lifetime, the first system will have to be replaced by a new system in 2001 and the second system in 2002.

Table 6.3-1. Costs Incurred in Operating a DBS System
(in 1982 dollars)

SHUTTLE ONLY CASE	SPACE STATION AVAILABLE CASE
A. LAUNCH COSTS:	A. LAUNCH COSTS:
i. Shuttle cost of $62M per DBS satellite.	i. Shuttle cost of $62M per DBS satellite.
ii. Integration cost of $9.5M per DBS satellite.	
B. SATELLITE COSTS:	B. SATELLITE COSTS:
i. Spacecraft cost of $95M per DBS satellite.	i. Spacecraft cost of $95M per DBS satellite.
ii. Feed horn costs of $1M each.	ii. Feed horn costs of $1M each.
iii. Switchable systems at $1M each.	
C. --	C. RECONFIGURATION AND SERVICING COSTS:
	i. Recurring cost of $7.4M per satellite reconfigured.
	ii. One time nonrecurring cost of $4M per DBS system.

The Space Station case will have one launch each year from 1991 to 1998. Servicing and refurbishing would start in 1993 at a rate of one satellite a year and increase one per year until it reaches eight per year and continues through to 2002.

At the end of the year 2002 various satellites in different DBS systems, for both scenarios, will have some operational lifetime remaining. This study only looks at the period 1992 to 2002 and assumes that there is no salvage value for satellites with any operational lifetime remaining. One way of rationalizing this is to assume that demand for DBS systems falls off at the end of year 2002 and thus any DBS satellite still operational is useless. Given this assumption and the fact that the services rendered in either scenario is the same, the net benefit of the presence of a Space Station is the difference between the costs of operating and deploying satellites in the two scenarios. The cost streams for the Shuttle only case and the Space Station case, and net benefits due to the presence of a Space Station are summarized in Table 6.3-2.

6.4 HIGH INCLINATION SPACE STATION

This part of the study looks at the net benefits of conducting noncommercial experiments that are performed with a high inclination Space Station instead of without it. The first benefit of the availability of a high inclination Space Station is less automation and redundancy needed for each payload. This translates into a reduction in payload development costs. The second benefit of the availability of a Space Station is the lower cost of servicing the payload from a Space Station. The major cost reduction in this case is the elimination of shuttle servicing revisits to the payload itself. Instead, Space Station crew are involved in servicing and refurbishing.

Table 6.4-1 lists the payloads, their launch dates, and their development costs with or without the availability of a high inclination Space Station. Table 6.4-2 summarizes the total number of STS revisits to service payloads each year without a Space Station against the total number of man days needed each year for servicing payloads if a high inclination Space Station is available.

Table 6.3-2. Space Station Cost-Benefit Case Study—DBS

	Discount Rate	Value of Cost Streams Discounted to 1991 (in millions of 1982 dollars)												Total Discounted Costs
		1991	1992	1993	1994	1995	1966	1997	1998	1999	2000	2001	2002	
Without Space Station	10%	823.0	748.11	679.80	618.07	562.11	511.08	464.17	422.20	0	0	316.85	288.05	5433.44
	15%	823.0	716.01	622.19	540.71	470.76	409.03	355.54	309.45	0	0	203.28	176.94	4626.90
With Space Station	10%	689.5	626.75	575.64	528.93	486.09	446.56	409.75	376.49	24.14	25.10	25.64	25.90	4240.49
	15%	689.5	599.86	526.86	462.72	407.09	357.39	313.85	275.95	16.94	16.81	16.45	15.91	3699.33

Net benefit due to the availability of Space Station (at 10% discount rate)* = 1192.95M 1982 dollars

Net benefit due to the availability of Space Station (at 15% discount rate)* = 927.57M 1982 dollars

* a) Since services supplied in both cases are the same, net benefits are the differences in costs incurred.

b) Satelites with active lives remaining after the end of 2002 are assumed to have no salvage value.

TABLE 6.4-1. PAYLOAD DEVELOPMENT COSTS

Year Launched	Payload	Development Costs, $ millions With Platform	With Space Station
1993	Earth Observation Platform	360	252
1997	UARS	507	354
1992, 1996	Space Science Subsatellite	200	140
1995	SAR	301	210
1993, 2000	Space Physics Pallet	300	210
1994	VLBI/Cosmic Ray obs	400	280
1998	LIDAR	425	298

TABLE 6.4-2. SUMMARY OF SERVICING OF HIGH INCLINATION PAYLOADS

	Without Space Station Total STS Servicing Revisits	With Space Station Total Space Station (new-time for Servicing Man days)
1991	0	0
1992	1	2.1
1993	3	206.1
1994	2	271.0
1995	3	276.0
1996	4	278.1
1997	4	369.1
1998	5	374.1
1999	4	372.0
2000	5	426.0
2001	4	426.0
2002	4	426.0
2003	4	426.0
2004	4	426.0
2005	4	426.0

Table 6.4-3 summarizes the net benefits derived from the availability of a high inclination Space Station. From Table 6.4-3 it can be seen that each one of the missions is more cost-effective using a space station. This is reflected by the positive net benefits for each mission due to the availability of the high inclination space station. The net benefits range from the lowest for the Earth Observation Platform to the highest for VLBP/Cosmic Ray Observation. Since the net benefit for all individual missions is positive, the total net benefit due to the availability of the high inclination space station is positive—$1385.69M 1982 dollars at a 10% discount rate or $1199.29M 1982 dollars at a 15% discount rate. So, it is definitely more beneficial to have a high inclination space station and the benefits are derived mainly due to the cost-effectiveness in the high inclination space station scenarios.

Table 6.4-3. **High Inclination Space Station Cost-Benefit Analysis**

Total Cost of Missions Discounted to 1992
(in milions of 1982 dollars)

	Discount Rate	Space Science Subsatellite	Earth Obs. Platform	Space Physics Pallet	VLBI/Cosmic Ray Obs.	SAR	UARS	LIDAR	Total Discounted Costs of All Missions
With Space Station	10%	298.64	448.41	396.42	350.72	204.07	352.99	186.21	2237.46
	15%	279.80	399.26	342.27	310.48	177.97	272.50	142.37	1924.65
Without Space Station	10%	433.06	452.27	531.85	810.47	385.23	627.27	383.00	3625.15
	15%	402.31	432.87	536.35	670.15	332.54	469.21	280.51	3125.94
Net	10%	134.42	3.86	135.43	459.75	181.16	274.28	196.79	
Benefits* Per Mission	15%	122.51	33.61	194.08	359.67	154.57	196.71	138.14	

Total net benefit due to the availability of High Inclination Space Station (at 10% discount rate) = 1385.69M 1982 dollars

Total net benefit due to the availability of High Inclination Space Station (at 15% discount rate) = 1199.29M 1982 dollars

* Since the missions achieve the same objectives in both scenarios, net benefits are the differences in costs incurred.

Table 6.4-3. High Inclination Space Station Cost-Benefit Analysis Cont'd

	Discount Rate	Total Cost of Missions Discounted to 1992 (in milions of 1982 dollars)							
		Space Science Subsatellite	Earth Obs. Platform	Space Physics Pallet	VLBI/Cosmic Ray Obs.	SAR	UARS		LIDAR
With	10%	298.64	448.41	396.42	350.72	204.07	352.99	186.21	2237.46
Space Station	15%	279.80	399.26	342.27	310.48	177.97	272.50		

APPENDIX 1

SUMMARY OF STUDY TASKS AND FINAL REPORT TOPICAL CROSS REFERENCE

SUMMARY OF STUDY TASKS

The study accomplished 3 major objectives:

1. Identified, collected, and analyzed science, applications, commercial, national security, technology development and space operations missions that require or benefit by the availability of a permanently manned space station. The space station attributes and characteristics that will be necessary to satisfy these requirements were identified.
2. Identified alternative space station architectural concepts that would satisfy the user mission requirements.
3. Performed programmatic analyses to define cost and schedule implications of the various architectural options.

Figure A-1 shows the summary task flow that was used to accomplish these objectives.

In Tasks 1.1 thru 1.5, missions were identified, screened, and their needs and benefits analyzed. Mission investigators were assigned to each of the mission classes (science and applications, commercial, technology development, space operations, and national security). In general, these investigators (and their supporting subcontractors) contacted potential users and analyzed available data to characterize potential mission needs. They worked in conjunction with designers and operations analysts to characterize the potential payloads and operational interfaces. In Task 1.6, the missions were allocated to orbits, and were assigned to platforms, free-flyers, or space stations, as appropriate. During Task 1.7, the various missions were integrated into time-phased mission models. The time-phasing took into account available budgetary constraints, prioritization, time sequencing constraints, and transportation availability. A computer program was used to process the integrated time-phased mission model to derive a year-by-year shuttle manifest schedule. The computer program was also used for Task 1.8 to derive the integrated time-phased space station accommodation requirements, i.e., power and thermal demands, berthing requirements, and crew skills. These mission analyses have been reported in Volume 2 of the final report.

Also included in Volume 2 are the results from Task 1.10. In this task, some of the primary commerical opportunities were examined to define the economics of the use of a space station and to define the benefits of doing business on a space station relative to doing it using the shuttle.

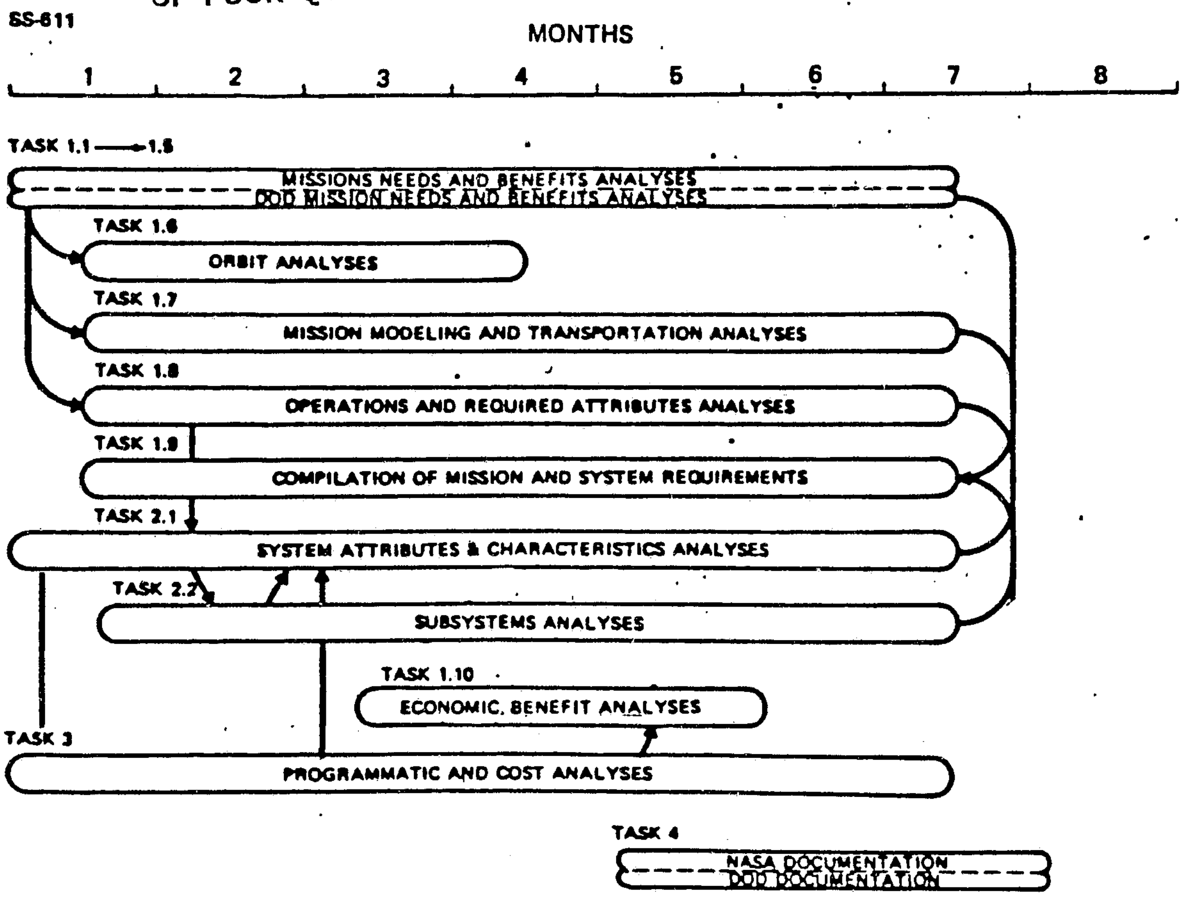

Figure A-1. Summary Diagram Outlines Major Task Traffic

In Task 1.9, mission requirements and space station design requirements were identified. An aggregate of these requirements are reported in Volume 3.

Volume 4 of the final report contains the results from Tasks 2.1, 2.2 and 3. Specifically in Task 2.1, a methodology for defining realistic architectural options was established. This methodology was applied using the requirements defined in the previous tasks. From this, we have created 3 architectural options and have shown some reference space station configuration concepts for each architectural option. Task 2.2 was performed to obtain analysis and trades of some of the principle subsystems, i.e., data management, environmental control and life support, and habitability. Task 3 provides the analyses of programmatics and cost options associated with the concepts derived during the study.

A cross reference guide to enable locating study topics within the volumes and volume sections of the final report is presented in Table A-1.

TABLE A-1

Final Report Topical Cross Reference Guide

Topic	Vol. 1 Exec Summ	Vol. 2 Mission Anal	Vol. 3 Rqm'ts	Vol. 4 Archit	Vol. 5 DoD	Vol. 6 Final Brief	Vol. 7-1 Sci/App Data Book	Vol. 7-2 Commer Data Book	Vol. 7-3 Tech Demo Data Book	Vol. 7-4 Archit Data Book	Vol. 7-5 Mission Data Book
Commercial Missions											
o Communication Satellites	o	3.2.1				o		o			
o Reconfigurable											
o Multibeam											
o Materials Proc.	o	3.2.2		I-1.3.2.3, 1.2.2.1		o		o			
o Semiconductors											
o Biological											
o Glass Fibers											
o Earth Observation		3.2.3									
Industrial Services		3.2.4						o			
o Crew Selection & Training											
o In-Space OPS											
Technology Demo's	o	3.3				o			o		
Space Operation	o	3.4				o					
o Construction											
o Flight Support											
o Servicing											

TABLE A-1

Final Report Topical Cross Reference Guide

Topic	Vol. 1 Exec Summ	Vol. 2 Mission Anal	Vol. 3 Rqm'ts	Vol. 4 Archit	Vol. 5 DoD	Vol. 6 Final Brief	Vol. 7-1 Sci/App Data Book	Vol. 7-2 Commer Data Book	Vol. 7-3 Tech Demo Data Book	Vol. 7-4 Archit Data Book	Vol. 7-5 Mission Data Book
Science & Applications Missions											
o Space Environment Missions	o	3.1.2				o	o				
o Astrophysics Missions	o	3.1.3				o	o				
o Earth Environment Missions	o	3.1.4				o	o				
o Life Sciences Missions	o	3.1.5				o	o				
o Materials Science Missions	o	3.1.6					o				
Scenarios of Operational Capabilities	o	4.0, 5.0				o					
o Mission Constrained o Station Constrained o No Space Station											

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Final Report Topical Cross Reference Guide

Topic	Vol. 1 Exec Summ	Vol. 2 Mission Anal	Vol. 3 Rqm'ts	Vol. 4 Archit	Vol. 5 DoD	Vol. 6 Final Brief	Vol. 7-1 Sci/App Data Book	Vol. 7-2 Commer Data Book	Vol. 7-3 Tech Demo Data Book	Vol. 7-4 Archit Data Book	Vol. 7-5 Mission Data Book
Mission Requirements Summary		5.0									o
o Low Inclination Space Station	o	5.2,5.3	3.2.1	I-1.2.2.4		o					o
o High Inclination Space Station	o	5.2,5.3		I-1.2.2.4		o					o
o Platform only	o	5.4				o					o
o Manifesting o Shuttle o OTV o TMS	o	5.2, 5.3, 5.4				o					o
o Crew Size	o	5.2,5.3 5.4	3.2.1			o					o
o Crew Skills		5.2.5.3 3.1.2.5, 3.1.3.5, 3.1.4.5, 3.1.5.5, 3.2.1.5, 3.2.2.6, 3.2.3 3.3		II-2.2.3							o

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Topic	Vol. 1 Exec Summ	Vol. 2 Mission Anal	Vol. 3 Rqm'ts	Vol. 4 Archit	Vol. 5 DoD	Vol. 6 Final Brief	Vol. 7-1 Sci/App Data Book	Vol. 7-2 Commer Data Book	Vol. 7-3 Tech Demo Data Book	Vol. 7-4 Archit Data Book	Vol. 7-5 Mission Data Book
Mission Requirements Summary (Continued)											
o Accommodations Reqm'ts	o	2.2 5.2,5.3	3.2.1			o					o
o Power		5.4	I-1.2.1.2, 1.2.2.4 1.2.3.3 1.2.3.4								
o Internal Vol											
o Berthing Ports											
Benefits		6.0									
o Semiconductor Manufacturing	o	6.2				o					o
o Glass Fiber Manufacturing	o	6.3				o					o
o Communications Satellite Assembly	o	6.4				o					o
o Biological Materials Manufacturing	o	6.5				o					o

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Mission Analysis											
o Manifesting Analysis Software	o	2.2				o					o
o Accommodations & Crew Activity Analysis Software o Crew Skills o Crew Size o Berthing Ports o Electrical power o Internal volume	o	2.2				o					o
Design Requirements											
o Mission Accommodation Reqm'ts		5.0	3.2								
o Interfaces											
o Berthing/Docking Port				II-10.0 I-1.3.2.1						o	
o Hangar		3.3		I-1.3.2.2							

TABLE A-1

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Architectural Options											
o Architecture Development Methodology	o			I-1.1		o				o	
o Space Station Architectural Options	o			I-1.2		o				o	
Build-up and Growth	o	5.0		I-1.2.3.4, 1.3.1.3, 1.3.2.3, 1.3.3.3							
Data Management											
o Architecture				II-3.2						o	
o In-Flt Checkout				II-3.3						o	
o Space-Ground Integration				II-3.4						o	
o Ground Lab				II-3.5						o	
o Software Devel.				II-3.6						o	
o Hardware Stds				II-3.7						o	
o Software Stds				II-3.8						o	
o Verif/Valid.				II-3.9						o	

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Logistics/Resupply											
o Logistics Module				II-7.1, 7.3,7.4							
o Resupply Reqm'ts				II-7.2							
Environmental Control and Life Support Subsystem				II-5.0						o	
o ECLS Evolution				II-5.2.1, 5.3.2						o	
o Safe Haven Logistics Module				II-5.2.1						o	
o Air Revitalization System				II-5.0,5.3.2						o	
o Water Revitalization System				II-5.0,5.3.2						o	
o Performance and Loads Specification										o	
o Overboard Venting				II-5.2.1,5.2.2						o	
o Architecture				II-5.2.1						o	
o Water Recovery System				II-5.0,5.3.2						o	
o CO_2 Concentration				II-5.0,5.3.2						o	
o Regenerative-Fuel-Cell-Based ECLS				II-5.0,5.2.1, 5.3.2						o	
o Recommendations				II-5.0, 5.3.2						o	
EVA/EMU				II-5.0, 5.2.2						o	

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Communications & Tracking Subsystem			3.2.2.1.11	II-4.0						o	
Manipulator System				II-6.0						o	
Pointing Systems				II-8.0						o	
Thermal Management				II-9.0						o	
Crew				II-2.0							
o Tasks				II-2.2							
o Skills		5.2.5.3 3.1.2.5, 3.1.3.5, 3.1.4.5, 3.1.5.5, 3.2.1.5 3.2.2.6, 3.2.3 3.3		II-2.2.3						o	
o Capabilities				II-2.2.2						o	
o Role Relationships				II-2.3.2						o	
o Accommodations			3.2.2.1.11	II-2.4						o	

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Crew (Continued)											
o Habitability	o		3.2.2.1.11	II-2.0,2.4						o	
o IVA Work Stations				II-2.5.2						o	
o EVA Work Stations				II-2.5.3 II-5.2.2						o	
o Maintenance				II-2.5.4						o	
o Stowage			3.2.2.1.11							o	
o Windows			3.2.2.1.11	II-2.4.1						o	
o Hygiene			3.2.2.1.11	II-2.4.2.4						o	
o Scheduling			3.2.2.1.11	II-2.3.1						o	

APPENDIX 2

KEY TEAM MEMBERS

KEY TEAM MEMBERS

Subject	Boeing Team	Subcontractor Team	
Study Manager	Gordon Woodcock	ADL:	Dr. Peter Glaser
		Battelle:	Kenneth E. Hughes
		ECON:	John Skratt
		ERIM:	Albert Sellman
		Hamilton Standard:	Harlan Brose
		Intermetrics:	John Hanaway
		Life Systems:	Franz Shubert
		MRA:	Col. Richard Randolph (Ret.)
		NBS:	Dr. B. J. Bluth
		RCA:	Dr. Herbert Gurk
		SAI:	Dr. Hugh R. Anderson
Technology Manager	Dr. Richard L. Olson		
Mission Analysis			
Science & Applications	Dr. Harold Liemohn David Tingey (Earth Obs.) Dr. Derek Mahaffey (Mission Integration) Melvin W. Oleson (Life Sciences) Dr. Robert Spiger (Plasma physics, astro-physics, solar physics)	SAI:	Dr. Hugh R. Anderson (Environmental Science) Dr. Peter Hendricks (Meterology/ Oceanography) Dr. Gil Stegen Dr. John Wilson (Life Sciences) Dr. Robert Loveless (Integration) Dr. Robin Muench Dr. Stuart Gorney (Life Sciences) Ms. Monica Dussman (Life Sciences)
		ERIM:	Albert Sellman (Earth Obs.) Dr. Irvin Sattinger (Earth Obs.)
Commercial	Dr. Harvey Willenberg	RCA:	Dr. Herbert Gurk Thaddeus (Ted) Hawkes
		ADL:	Dr. Peter Glaser
		Battelle:	Dr. Kenneth E. Hughes
		MRA:	Col. Richard Randolph (Ret.) Robert Pace

KEY TEAM MEMBERS (Cont'd)

Subject	**Boeing Team**	**Subcontractor Team**	
Mission Analysis (Cont'd)			
Technology Demonstrations	George Reid Dr. Alan G. Osgood David S. Parkman Steve Robinson Richard Gates Tim Vinopal		
National Defense	Robert S.Y. Yoseph	ERIM:	Mirko Najman
Space Operations	Keith H. Miller		
Architecture and Subsystems			
Architecture & Configurations	John J. Olson Brand Griffin Tim Vinopal David S. Parkman Steve Robinson		
Communications		RCA:	Donald McGiffney
Crew Systems	Keith H. Miller George Reid Dr. Alan G. Osgood	NBS:	Dr. B. J. Bluth
Data Management and Software	Les Holgerson	Intermetrics:	John Hanaway
ECLSS	Keith H. Miller	Ham Std: Life Systems:	Harlan Brose Ross Cushman Al Boehm Ken King Todd Lewis Dr. R. A. Winveen Franz Schubert Dr. Dennis B. Heppner
Operations Analysis	Keith H. Miller George Reid Dr. Alan G. Osgood		
Orbit Analysis	Dani Eder		

KEY TEAM MEMBERS (Cont'd)

Subject	Boeing Team	Subcontractor Team	
Architecture and Subsystems (Cont'd)			
Orbit/Survivability Analysis	Stephen W. Paris Merri Anne Stowe		
C^3I	H. Paul Janes		
Radiation Effects	Dr. William C. Bowman		
Requirements Analysis	Lowell Wiley		
Programmatics & Cost			
Cost Analysis	Ken verGowe	ECON:	Ed Dupnick
Programmatics	Gordon Woodcock		

APPENDIX 3

ACRONYMS AND ABBREVIATIONS

LIST OF ACRONYMS AND ABBREVIATIONS

AAP	Airlock Adapter Plate
AC	Alternating Current
ADM	Adaptive Delta Modulation
AM	Airlock Module
APC	Adaptive Predictive Coders
APSM	Automated Power Systems Management
ACS	Attitude Control System
ARS	Air Revitalization System
ASE	Airborn Support Equipment
BIT	Built in Test
BITE	Built in Test Equipment
CAMS	Continuous Atmosphere Monitoring System
C&D	Controls and Displays
C&W	Caution and Warning
CCA	Communications Carrier Assembly
CCC	Contaminant Control Cartridge
CCTV	Closed Circuit Television
CEI	Critical End Item
CER	Cost Estimating Relationship
CF	Construction Facility
CMG	Control Moment Gyro
CMD	Command
CMDS	Commands
CO_2	Carbon Dioxide
CPU	Computer Processor Units
CRT	Cathode Ray Tube
dB	Decibels
DC	Direct Current
DCM	Display and Control Module
DDT&E	Design, Development, Test, and Evaluation
DOD, DoD	Department of Defense
DT	Docking Tunnel
DM	Docking Module
DMS	Data Management System
DSCS	Defense Satellite Communications System
ECLSS	Environmental Control/Life Support System
EDC	Electrochemical Depolarized CO_2 Concentrator
EEH	EMU Electrical Harness
EIRP	Effective Isotropic Radiated Power
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
ET	External Tank
EVA	Extravehicular Activity
EVC	EVA Communications System
EVVA	EVA Visor Assembly
FM	Flow Meter
FMEA	Failure Mode and Effects Analysis
ftc	Foot candles
FSF	Flight Support Facility
FSS	Fluid Storage System
GaAs	Gallium Acsenide

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

GN&C	Guidance, Navigation and Control
GEO	Geosynchronous Earth Orbit
GHZ	Gigahertz
GPC	General Payload Computer
GPS	Global Positioning System
GSE	Ground Support Equipment
GSTDN	Ground Satellite Tracking and Data Network
GFE	Government Furnished Equipment
GTV	Ground Test Vehicle
HLL	High Level Language
HLLV	Heavy Lift Launch Vehicle
HM	Habitat Module
HMF	Health Maintenance Facility
HPA	Handling and Positioning Aide
HUT	Hard Upper Torso
Hz	Hertz (cycles per second)
ICD	Interface Control Document
IDB	Insert Drink Bag
IOC	Initial Operating Capability
IR	Infrared
IVA	Intravehicular Activity
JSC	Johnson Space Center
KBPS	Kilo Bits Per Second
KM, Km	Kilometers
KSC	Kennedy Space Center
lbm	Pounds Mass
LCD	Liquid Crystal Display
LCVG	Liquid Cooling and Ventilation Garment
LED	Light Emitting Diode
LEO	Low Earth Orbit
LiOH	Lithium Hydroxide
LM	Logistics Module
LPC	Linear Predictive Coders
LRU	Lowest Replaceable Unit
LSS	Life Support System
LTA	Lower Torso Assembly
LV	Launch Vehicle
lx	Lumens
MBA	Multibeam Antenna
mbps	Megabits per second
MHz	Megahertz
MMU	Manned Maneuvering Unit
MM-Wave	Millimeter wave
MOTV	Manned Orbit Transfer Vehicle
MRWS	Manned Remote Work Station
MSFN	Manned Space Flight Network
N/A	Not Applicable
NBS	National Bureau of Standards
NSA	National Security Agency
N	Newton
NiCd	Nickel Cadmium
NiH_2	Nickle Hydrogen

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

Nm,nm	Nautical miles
N/m^2	Newtons per meter squared
OBS	Operational Bioinstrumentation System
OCS	Onboard Checkout System
OCP	Open Cherrypicker
OMS	Orbital Manuevering System
OTV	Orbital Transfer Vehicle
PCM	Pulse Code Modulation
PCM	Parametric Cost Model
PEP	Power Extension Package
PIDA	Payload Installation and Deployment Apparatus
P/L	Payload
PLSS	Portable Life Support System
PM	Power Module
POM	Proximity Operations Module
ppm	Parts per Million
PRS	Personnel Rescue System
PSID	Pounds per Square Inch Differential
RCS	Reaction Control System
REM	Roentgen Equivalent Man
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Remote Manipulator System
RPM	Revolutions Per Minute
RPS	Real-time Photogrammetric System
SAF	Systems Assembly Facility
SAWD	Solid Amine Water Desorbed
SPGaAs	Space Produced Gallium Arsenide
scfm	Standard Cubic Feet per Minute
SCS	Stability and Control System
SCU	Service and Cooling Umbilical
SDV	Shuttle - Derived Vehicle
SDHLV	Shuttle - Derived Heavy Lift Vehicle
SEPS	Solar Electric Propulsion System
SF	Storage Facility
SM	Service Module
SOC	Space Operations Center
SOP	Secondary Oxygen Pack
SRB	Solid Rocket Booster
SRMS	Shuttle Remote Manipulative System
SRU	Shop Replacable Units
SSA	Space Suite Assembly
SSME	Space Shuttle Main Engine
STS	Space Transportation System
SSP	Space Station Prototype
STAR	Shuttle Turnaround Analysis Report
STDN	Spaceflight Tracking and Data Network
STE	Standard Test Equipment
TBD	To Be Determined
TDRSS	Tracing and Data Relay Satellite System
TFU	Theoretical First Unit
TGA	Trace Gas Analyzer

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

TIMES	Thermoelectric Integrated Membrane Evaporation System
TLM	Telemetry
TM	Telemetry
TMS	Teleoperator Maneuvering System
TT	Turntable/Tilttable
TV	Television
UCD	Urine Collection Device
VCD	Vapor Compression Distillation
VDC	Volts Direct Current
VLSI	Very Large Sacle Integrated Circuits
VSS	Versatile Servicing Stage
WBS	Work Breakdown Structure
WMS	Waste Management System

APPENDIX 4

MANIFESTING CODE INPUT DATA FORMS

MANIFESTING CODE INPUT DATA FORMS

This appendix describes the payloads data input requirements for the automated STS manifesting and space station accommodations analysis routine. The first section describes the data content and the second section summarizes format requirements.

The program deals with STS or space station payloads. These may or may not correspond to missions. In the case, for example, of a communications satellite, the mission (launch a series of satellites) corresponds exactly to a payload. In the case of a life sciences mission, the mission may share a set of instruments housed in a laboratory module. The same instruments will serve other missions. The payload is the laboratory module itself.

Key

Each payload is given a key designator that identifies the mission type, e.g., "SA" is science, astrophysics, and includes a sequential count. The first astrophysics mission, for example, will have a key "SA01." The computer really cares only about the type designator; it is used to assign crew skills. Table 1 summarizes mission keys.

Title

Each payload is given a title of two lines, 16 characters each. Blanks (spaces) count as characters. Titles are used only for labeling. They are not processed.

Altitude

Each payload is assigned a mission altitude in kilometers. This is informative only. Altitude data are not processed.

Inclination

Each payload is assigned an orbit inclination in degrees. This value is used to assign payloads to a low-inclination (29-deg) or high-inclination (98-deg) station. Intermediate inclinations such as 60 degrees are not meaningful in this analysis. See "manifesting restrictions" for other relevant information.

Delta V (3 values)

Delta V's are assigned to those payloads that require an upper stage for delivery to a destination orbit. A non-zero delta v implies that the mission itself cannot be performed onboard a space station. A typical use of delta v is for geosynchronous payloads. The three delta v values are: (1) delivery, (2) return, and (3) return if the upper stage is aerobraked. A return value of zero implies that return of the upper stage is impossible. If the payload need not be returned, a return mass of zero is entered (see below). Return delta v values are used in selecting upper stage modes whether or not the payload is to be returned.

Masses

Three mass values, in metric tons, are entered: (1) Delivery Mass, (2) Support Mass, and (3) Return Mass. Delivery mass is the normal payload mass. Support mass is the mass of any extra equipment that would have to be carried to orbit if a space station were not available. A typical example is the mass of satellite servicing equipment needed to carry out a satellite servicing mission using only the shuttle. A further example is construction equipment. Return mass is the payload return mass, if the payload is to be returned. It is used to calculate upper stage performance, e.g., for manned missions to high-energy orbits where the crew cab is carried up and down. In instances where the payload is delivered and returned sometime later, the return requirement is entered as a minus value (typically -1) in the traffic model. The delivery mass is then treated as a return mass for upper stage performance.

Lengths

Payload lengths, in meters, are used in manifesting the STS and accordingly are stowed lengths. Payload and auxiliary lengths are required. The auxiliary length is analogous to the auxiliary mass—extra length required in the shuttle payload bay if a space station is not available. If a payload can be manifested in such a way as to not take up space in the payload bay, a length of zero is permitted.

Diameter

Payload diameter, in meters, is input but is informative only.

Power

If the payload requires power from the space station, the power in kilowatts is input here. Input the value of normal operating power. Operating time (see below) is used by the program to get average power. If the payload does not need power, or gets it from a free-flyer platform, the value here is zero. Don't estimate power for servicing need such as construction; that is separately accounted. Power values should be those required to operate the mission.

Internal Volume

This is internal volume, in cubic meters, required of the space station. If the payload is a dedicated module such as a life sciences module, the internal volume is zero; the payload provides its own. But if the payload is an instrument such as an SAR that has electronics to be placed in the pressurized volume for maintenance access, a non-zero value must be entered.

Point

Pointing requirements must be designated as "Earth," "inertial," or "none."

Manifesting Restriction

This is used in several ways. A restriction of zero implies no restrictions. A value of 1 says "manifest only with other 1's." A value of 2 says "manifest alone." A value of 3 says that the docking module installed in the front of the payload bay must be used (e.g., for space station resupply).

Payload Code

This is an operations code that tells the program certain things about the payload. A summary of operations codes is provided in table 2.

Time Entries

Time entries are used in calculations of shuttle time on orbit, space station occupancy, and crew requirements. A summary of the time values required is presented in table 3. Those times relating to crew involvement should be estimated on the basis that one "day" is one man, one six-hour shift. EVA's will always be charged for two crews for safety reasons.

Construction Time

Construction items include the length of space-manufactured beam to be produced, the number of appendages to be installed (a subsystem box or optical reflector subelement counts as an appendage), and the number of modules to be installed. Modules are counted as complete subassemblies or transportable modules that will be installed on a berthing port or equivalent. Internal algorithms are provided for estimating the crew time and equipment needed to carry out the construction operations implied by these item counts.

Traffic Data

Traffic data are input as payloads per year. These values are integers, i.e., if two of payload X fly in a certain year, the value entered for that year is 2.

A one-to-one correspondence is maintained between the payload and traffic files. Accordingly, if a certain payload is not to be flown at all in a particular traffic model, its traffic file can be entered as all zeros. The computer will then ignore that payload. This avoids altering the payloads file for such trade studies as low, median, and high traffic models.

Payloads to be returned to Earth are designated by negative values in the traffic file. The computer uses this information in two ways: (1) if the payload requires an upper stage, an upper stage mission is manifested with a zero delivery and finite return payload; and (2) if the payload involves operations such as periodic servicing, the servicing missions are "turned on" when the payload is launched and "turned off" when it is returned.

TABLE 1. MISSION KEYS

Type	Sub-Type	Mission Key
Science and Application	Astrophysics	SAXX
	Earth and Plan	SPXX
	Environmental	SEXX
	Life Science	SLXX
	Materials Processing	SMXX
	Earth/Ocean/Climate Obs.	SOXX
Commercial	Earth and Ocean Obs.	SOXX
	Commun.	CCXX
	Material Processing	CMXX
	Industrial Service	CIXX
Technical Development	Materials and Structure	TMXX
	Energy Conservation	TEXX
	Computer Science and Elex.	TCXX
	Propulsion	TPXX
	Controls and Human Factors	THXX
	Space Station System and Operations	TSXX
	Fluid and Thermal Physics and Chemistry	TFXX
	DoD	TDXX
Operations	Maintenance	MMXX
	Construction	COXX
	Satellite Servicing (Remote)	SIXX
	Satellite Servicing (at Space Station)	SEXX
	Transportation	TTXX
	Manned OTV	MOXX

TABLE 2. MISSION OP CODES

These codes provide additional information to the mission code:

2 to 4 characters CHARACTER #4

Payload Classes		Op Code
Free Flyer	Not Serviced	F
	Remote TMS	FT
	Remote Manned	FM
	Serviced at Station (TMS Ret.)	FL
	Serviced at Station (Self-Prop)	FS
Platform-Based	Not Serviced	P
	Remote TMS	PT
	Remote Manned	PM
	Serviced at Station (TMS Ret.)	PL
	Serviced at Station (Self-Prop)	PS
Space Station Based		SS
Sortie (i.e., a payload that returns on the same shuttle fligth launched on)		SR

For construction or servicing missions, third character is C and fourth character is L, M, or H, for low, medium, or high complexity.

X's can be used to fill (i.e., FXXH).

TABLE 3. TIMES

Item	Definition
J,1	Same - Transportation operations duration for OTV missions (zero otherwise)
J,2	Same - OTV or TMS staytime on orbit
J,3	USE - Mission use, days/year, for station or platform-based mission
J,4	SERVICE IVA - Man-days/year for all forms of service - maintenance, repair, replenish, calibration, etc.
J,5	SERVICE EVA - Same for EVA ops.
J,6	EXP OPS - Man-days/year for experiment ops. assumed on space station
J,7	Service frequency times/year

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MANIFESTING CODE INPUT

KEY	S001
TITLE 1	EARTH OBSERV
TITLE 2	PALLET
ALT	400
INCL	98
ΔV 1,2,3	0,0,0
DEL M	3.500
SUP M	2
RET M	3.5
DEL L	7
SUP L	2
DIA	4
PWR	3.5
INT VOL	2.5
POINT	EARTH
MANIF RESTR	NONE
P/L CODE	SPCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	300
T4 IVA serv	16
T5 EVA serv	16
T6 Msn Ops	150
T7 Serv Freq	1
Beam L	0
N. App	5
N. Modules	1

Traffic:

90	91	92	93
0	0	0	1

94	95	96	97	98	99
0	0	0	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
412	Microwave Radiom	55	2 (0.3)	1	EARTH	150	2	2	10	1
403	Linear MSS	300	3 (0.2)	1	EARTH	200	2	2	15	1
-	Data Coll Pkg	30	1	0.1	EARTH	200	1	1	0	1
411	Radar Sounder	125	4	2	EARTH	150	1	1	10	1
402	Laser Ranger	180	3	1	EARTH	100	2	2	5	1
406	Battery of Cam	200	2 (1)	0.1	EARTH	100	2	2	20	1
407	Scattermeter	160	2	1	EARTH	60	2	2	40	1
401	Imaging Spect	210	2 (1)	2	EARTH	200	4	4	50	1
		1260	2.5	3.5						

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MANIFESTING CODE INPUT

KEY	S002	T1 (up-dn)	2
TITLE 1	SYNTH APERTURE	T2 (on orb)	0
TITLE 2	RADAR	T3 (use)	10
ALT	400	T4 IVA serv	2
INCL	98	T5 EVA serv	2
ΔV 1,2,3	0,0,0	T6 Msn Ops	5
DEL M	2.5	T7 Serv Freq	1
SUP M	1		
RET M	2.5	Beam L	0
DEL L	6	N. App	2
SUP L	2	N. Modules	1
DIA	4		
PWR	10		
INT VOL	1		
POINT	EARTH		
MANIF RESTR	NONE		
P/L CODE	SPCL		

Traffic:

		90	91	92	93
		0	0	0	0
94	95	96	97	98	99
0	1	0	0	0	0
00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	S003
TITLE 1	HETERODYNING
TITLE 2	CO_2 LIDAR
ALT	400
INCL	98
ΔV 1,2,3	0,0,0
DEL M	1.2
SUP M	1
RET M	1.2
DEL L	3
SUP L	1
DIA	4
PWR	1
INT VOL	1
POINT	EARTH
MANIF RESTR	0
P/L CODE	SPXX

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	50
T4 IVA serv	2
T5 EVA serv	5
T6 Msn Ops	5
T7 Serv Freq	2
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	S004
TITLE 1	UPPER ATMOS
TITLE 2	RES PKG
ALT	400
INCL	98
ΔV 1,2,3	0,0,0
DEL M	4
SUP M	2
RET M	4
DEL L	7
SUP L	2
DIA	4.2
PWR	2.15
INT VOL	0.9
POINT	EARTH
MANIF RESTR	0
P/L CODE	SPCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	200
T4 IVA serv	35
T5 EVA serv	19
T6 Msn Ops	145
T7 Serv Freq	2
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	Hologen Occult Exp	100	0.1	0.2	EARTH	100	5	2	5	2
	Temp & Wind	65	0.1	0.2	EARTH	100	5	2	5	2
	Cryo Limb Etalon Spect.	453	0.2	1.0	EARTH	100	6	5	5	2
	Improved Stratosphere & Mesosphere Sounder	85	0.1	0.2	EARTH	50	2	2	0	2
	Microwave Limb Sounder	262	0.1	0.2	EARTH	100	2	2	0	2
	High-Res. Doppler Imager	76	0.1	0.2	EARTH	100	5	2	10	2
	Uv Solar	18	0.1	0.05	EARTH	200	5	2	60	2
	Solar UV Irradiance Monitor	95	0.1	0.1	EARTH	200	5	2	60	2
		1154								

MANIFESTING CODE INPUT

KEY	0T03
TITLE 1	SPACE STATION
TITLE 2	MODULES
ALT	400
INCL	98
ΔV 1,2,3	0,0,0
DEL M	11
SUP M	0
RET M	11
DEL L	7
SUP L	0
DIA	4
PWR	15
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SSSS

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	0
T4 IVA serv	150
T5 EVA serv	10
T6 Msn Ops	0
T7 Serv Freq	0
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
0	2	2	1

94	95	96	97	98	99
0	0	0	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

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MANIFESTING CODE INPUT

KEY	OT04	T1 (up-dn)	2
TITLE 1	HI-INCL STATION	T2 (on orb)	0
TITLE 2	RESUPPLY	T3 (use)	0
ALT	400	T4 IVA serv	0
INCL	98	T5 EVA serv	0
ΔV 1,2,3	0,0,0	T6 Msn Ops	0
DEL M	8	T7 Serv Freq	0
SUP M	0		
RET M	8	Beam L	0
DEL L	6	N. App	0
SUP L	0	N. Modules	0
DIA	4.4		
PWR	1		
INT VOL	0		
POINT	NONE		
MANIF RESTR	3		
P/L CODE	SORS		

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

MANIFESTING CODE INPUT

KEY	SP01
TITLE 1	SPACE SCIENCE
TITLE 2	SUBSATELLITE
ALT	400
INCL	98
ΔV 1,2,3	0,0,0
DEL M	2400
SUP M	1000
RET M	2400
DEL L	4
SUP L	1
DIA	4
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	FSXX

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	0
T5 EVA serv	5
T6 Msn Ops	10
T7 Serv Freq	1
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
0	0	1	0

94	95	96	97	98	99
-1	0	1	0	0	-1

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

C-4

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MANIFESTING CODE INPUT

KEY	SP02
TITLE 1	SPACE PHYSICS
TITLE 2	PALLET
ALT	400
INCL	98
ΔV 1,2,3	0,0,0
DEL M	10
SUP M	4
RET M	10
DEL L	5
SUP L	2
DIA	4
PWR	0.4
INT VOL	2
POINT	EARTH
MANIF RESTR	0
P/L CODE	SPCM

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	36
T4 IVA serv	17
T5 EVA serv	14
T6 Msn Ops	54
T7 Serv Freq	2
Beam L	0
N. App	20
N. Modules	3

Traffic:

90	91	92	93
0	0	0	1

94	95	96	97	98	99
0	0	0	-1	0	0
00	**01**	**02**	**03**	**04**	**05**
1	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL		PWR	POINT	USE	IVA	EVA	MSN	S.F.
201	Particle Accel	5800	4	(e)	10	EARTH	3	8	2	1	2
211	Imag UV-IR Spect	200	2 0.5	(e) (i)	1	EARTH	20	2	2	20	2
212	UV-IR Telescope	300	3 1	(e) (i)	1	EARTH	10	2	2	10	2
213	X-ray Tele (Atmos)	200	2 0.5	(e) (i)	0.3	EARTH	13	2	2	13	2
214	Mag Confine Lab	1000	4	(e)	5	EARTH	8	2	5	8	2
215	Retro Rell Track	1000	10	(e)	1	EARTH	5	1	1	2	2
		8500									

MANIFESTING CODE INPUT

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KEY	SA01
TITLE 1	VLBI/COSMIC
TITLE 2	RAY PKG
ALT	400
INCL	98
ΔV 1,2,3	0,0,0
DEL M	10
SUP M	2
RET M	10
DEL L	9
SUP L	3
DIA	4
PWR	2
INT VOL	1
POINT	INERT
MANIF RESTR	0
P/L CODE	SPCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	8
T5 EVA serv	9
T6 Msn Ops	67
T7 Serv Freq	2
Beam L	0
N. App	2
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
319	Shuttle Cosmic Ray	3000	8	0.5	NONE	365	1	1	5	1
302	VLBI	350	8	1.0	INERTIAL	200	4	2	50	2
311	HNE	200	2	0.5	NONE	365	1	1	2	2
		3550	18	2.0	INERTIAL	365	6	4	57	2
312	LACRD	4000	30	1.0	NONE	365	2	5	10	2

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OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	SL08
TITLE 1	RAD BIOLOGY
TITLE 2	IN SM MAMMALS
ALT	400
INCL	97
ΔV 1,2,3	0,0,0
DEL M	.3
SUP M	0
RET M	0
DEL L	0
SUP L	0
DIA	0
PWR	0.6
INT VOL	0.4
POINT	NONE
MANIF RESTR	0
P/L CODE	SSSA

T1 (up-dn)	2.
T2 (on orb)	0.
T3 (use)	365
T4 IVA serv	16
T5 EVA serv	0
T6 Msn Ops	30
T7 Serv Freq	4
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93		
0	0	0	0		

94	95	96	97	98	99
0	0	0	1	0	0
00	**01**	**02**	**03**	**04**	**05**
-1	0	0	1	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	SL01
TITLE 1	HUMAN LIFE SI
TITLE 2	CARRY-ONS
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	0.408
SUP M	0
RET M	0.408
DEL L	0
SUP L	0
DIA	0
PWR	1.7
INT VOL	3.4
POINT	NONE
MANIF RESTR	0
P/L CODE	SSSA

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	16
T5 EVA serv	0
T6 Msn Ops	73
T7 Serv Freq	12
Beam L	0
N. App	0
N. Modules	0

Traffic:

		90	91	92	93
		0	1	0	0
94	95	96	97	98	99
0	0	0	0	0	0
00	01	02	03	04	05
-1	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
503	Human Sensory System	0.177	0.1	0.4	NONE	150	0	0	15	4
501	Human Cardio Pulmonary	0.097	1.4	0.9	NONE	365	4	0	40	4
504	Human Musc-Skeletal	0.134	1.9	0.4	NONE	365	12	0	18	12

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MANIFESTING CODE INPUT

KEY	SL02	T1 (up-dn)	2
TITLE 1	SMALL MAMMALS	T2 (on orb)	0
TITLE 2	CARRY-ONS	T3 (use)	365
ALT	500	T4 IVA serv	133
INCL	29	T5 EVA serv	0
ΔV 1,2,3	0,0,0	T6 Msn Ops	41
DEL M	1.58	T7 Serv Freq	12
SUP M	0		
RET M	0	Beam L	0
DEL L	0	N. App	0
SUP L	0	N. Modules	0
DIA	0		
PWR	4.0		
INT VOL	3.4		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	SSSA		

Traffic:

90	91	92	93
0	1	0	0

94	95	96	97	98	99
0	-1	0	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
506	Muscle Loss, Small Mammals	256	.4	.6	NONE	365	18	0	7	12
510	Vestib. Phys. in Small Mammals	265	.4	.6	NONE	365	23	0	8	12
508	Nonhuman Cardio	256	.4	.7	NONE	365	18	0	11	12
509	Nonhuman Mammalian Metab.	291	1.4	.9	NONE	365	38.5	0	0	12
505	Bone Loss, Small Mammals	256	0.4	0.6	NONE	365	18	0	8	12
507	Fluid & Electro	256	.4	.6	NONE	365	18	0	7	12
		1580	3.4	4.0	-	365	133	0	41	12

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MANIFESTING CODE INPUT

KEY	SL03
TITLE 1	PLANT DEVEL
TITLE 2	CARRY-ONS
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	0.14
SUP M	0
RET M	0
DEL L	0
SUP L	0
DIA	0
PWR	0.5
INT VOL	1
POINT	NONE
MANIF RESTR	0
P/L CODE	SSSA

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	27.5
T5 EVA serv	0
T6 Msn Ops	14
T7 Serv Freq	12
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	1	0	0	0	0	-1	0	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
516	Plant Development	0.07	0.5	0.2	NONE	365	16	-	14	12
515	Plant Phys.	0.07	0.5	0.3	NONE	365	11.5	0	0	12

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MANIFESTING CODE INPUT

KEY	SL04
TITLE 1	LIFE SCIENCES
TITLE 2	RES FAC
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	5.56
SUP M	3
RET M	5.56
DEL L	7
SUP L	2
DIA	4.4
PWR	12.2
INT VOL	0
POINT	NONE
MANIF RESTR	3
P/L CODE	SPXX

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	145
T5 EVA serv	0
T6 Msn Ops	191
T7 Serv Freq	12
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	0	0	1	0	0	0	0	-1	0	1	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
511	Vestib Function	.26	0	.7	NONE	365	1.2	0	9.1	12
514	Repro In Small Mammals	5.3	0	11.5	NONE	365	144	0	182	12

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MANIFESTING CODE INPUT

KEY	SL05
TITLE 1	CENTRIFUGE
TITLE 2	(ADD TO LSRF)
ALT	500
INCL	30
ΔV 1,2,3	0,0,0
DEL M	0.5
SUP M	5.2
RET M	0.5
DEL L	3
SUP L	7
DIA	4.2
PWR	4
INT VOL	0
POINT	NONE
MANIF RESTR	3
P/L CODE	SSCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	240
T5 EVA serv	0
T6 Msn Ops	91
T7 Serv Freq	12
Beam L	0
N. App	0
N. Modules	1

Traffic:

90	91	92	93		
0	0	0	0		

94	95	96	97	98	99
0	0	0	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
513	ANIMAL DEVELOPMENT									

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MANIFESTING CODE INPUT

KEY	SL06	T1 (up-dn)	2
TITLE 1	CLOSED ENV	T2 (on orb)	0
TITLE 2	LSS EXPT MOD	T3 (use)	365
ALT	500	T4 IVA serv	24
INCL	29	T5 EVA serv	0
ΔV 1,2,3	0,0,0	T6 Msn Ops	547.5
DEL M	3.3	T7 Serv Freq	12
SUP M	2		
RET M	3.3	Beam L	0
DEL L	5	N. App	0
SUP L	2	N. Modules	1
DIA	4.2		
PWR	9.7		
INT VOL	0		
POINT	NONE		
MANIF RESTR	3		
P/L CODE	SPCL		

Traffic:

90	91	92	93		
0	0	0	0		
94	95	96	97	98	99
0	0	0	1	0	0
00	01	02	03	04	05
0	-1	0	1	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CM01
TITLE 1	MATLS SCIENCE
TITLE 2	LAB
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	12
SUP M	4
RET M	12
DEL L	7
SUP L	2
DIA	4
PWR	50
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SPXX

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	130
T4 IVA serv	60
T5 EVA serv	0
T6 Msn Ops	300
T7 Serv Freq	4
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	Float Zone Crystal	300	0	20	NONE	100	20	-	100	4
	Vapor Epitaxy Xtal	300	0	10	NONE	150	20	-	100	4
	Electro Epitaxy #1	1500	0	20	NONE	150	20	-	100	4

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MANIFESTING CODE INPUT

KEY	CM01	T1 (up-dn)	2
TITLE 1	FLOAT ZONE	T2 (on orb)	0
TITLE 2	CRYSTAL PROCESS	T3 (use)	300
ALT	500	T4 IVA serv	60
INCL	28.5	T5 EVA serv	
ΔV 1,2,3	0,0,0	T6 Msn Ops	100
DEL M	0.3	T7 Serv Freq	4
SUP M	1.0		
RET M	0.3	Beam L	0
DEL L	3.0	N. App	0
SUP L	4.0	N. Modules	0
DIA	1.5		
PWR	20.0		
INT VOL	30.0		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	SSCL		

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

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MANIFESTING CODE INPUT

KEY	CM02	T1 (up-dn)	
TITLE 1	VAPOR EPITAXIAL	T2 (on orb)	
TITLE 2	CRYSTAL GROWTH	T3 (use)	300
ALT	500	T4 IVA serv	60
INCL	28.5	T5 EVA serv	
ΔV 1,2,3	0,0,0	T6 Msn Ops	100
DEL M	3.0	T7 Serv Freq	10
SUP M	0.5		
RET M	3.0	Beam L	0
DEL L	0.5	N. App	0
SUP L	1.5	N. Modules	0
DIA	0.5		
PWR	10.0		
INT VOL	0.5		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	SSCL		

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	1	2	2	2	1	1	1	1	1	2	2	2	2	2	2

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
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MANIFESTING CODE INPUT

KEY	CM02
TITLE 1	CRYSTAL GROWTH
TITLE 2	FACTORY/PLAT
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	10
SUP M	2
RET M	10
DEL L	7
SUP L	2
DIA	4.2
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	PMCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	5
T5 EVA serv	4
T6 Msn Ops	0
T7 Serv Freq	4
Beam L	0
N. App	0
N. Modules	1

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	Electro Epitaxy #2 and #3									

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MANIFESTING CODE INPUT

KEY	CM03
TITLE 1	ELECTROEPITAXIAL
TITLE 2	CRYSTAL GROWTH 1
ALT	500
INCL	28.5
ΔV 1,2,3	0,0,0
DEL M	1.5
SUP M	1.0
RET M	1.5
DEL L	2.0
SUP L	4.0
DIA	2.0
PWR	20.0
INT VOL	20.0
POINT	NONE
MANIF RESTR	0
P/L CODE	SSCL

T1 (up-dn)	
T2 (on orb)	
T3 (use)	300
T4 IVA serv	60
T5 EVA serv	
T6 Msn Ops	100
T7 Serv Freq	10
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CM03
TITLE 1	CRYSTAL GROWTH
TITLE 2	RESUP-1
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	4
SUP M	1
RET M	4
DEL L	2
SUP L	4
DIA	2
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	PMXX

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	2
T4 IVA serv	2
T5 EVA serv	2
T6 Msn Ops	2
T7 Serv Freq	3
Beam L	0
N. App	0
N. Modules	1

Traffic:

90	91	92	93
0	0	0	0

94	95	96	97	98	99
3	3	3	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CM04
TITLE 1	ELECTROEPITAXIAL
TITLE 2	CRYSTAL GROWTH 2
ALT	500
INCL	28.5
ΔV 1,2,3	0,0,0
DEL M	4.0
SUP M	1.0
RET M	4.0
DEL L	2.0
SUP L	4.0
DIA	2.0
PWR	40.0
INT VOL	20.0
POINT	NONE
MANIF RESTR	0
P/L CODE	SSCL

T1 (up-dn)	
T2 (on orb)	
T3 (use)	300
T4 IVA serv	60
T5 EVA serv	
T6 Msn Ops	100
T7 Serv Freq	10
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
0	0	0	0

94	95	96	97	98	99
3	3	3	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CM04
TITLE 1	CRYSTAL GROWTH
TITLE 2	RESUP-2
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	12.5
SUP M	7
RET M	12.5
DEL L	4
SUP L	4
DIA	4
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	PMCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	2
T4 IVA serv	2
T5 EVA serv	2
T6 Msn Ops	0
T7 Serv Freq	4
Beam L	0
N. App	0
N. Modules	1

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	0	0	0	0	0	3	4	5	5	6	6	6	6	6

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	SA02
TITLE 1	TELESCOPE
TITLE 2	CLUSTER
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	20
SUP M	5
RET M	20
DEL L	12
SUP L	3
DIA	4
PWR	4
INT VOL	2
POINT	INERT
MANIF RESTR	0
P/L CODE	SPXX

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	17
T5 EVA serv	6
T6 Msn Ops	65
T7 Serv Freq	6
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
0	1	0	0

94	95	96	97	98	99
0	0	-1	0	1	0

00	01	02	03	04	05
0	0	0	-1	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
301	SIRTF (IR Telescope)	6500	144(e)	1	INERT	365	12	3	30	6
303	X-ray Tel	5000	30(e)	2.0	INERT	365	2	1	10	1
304	X-ray Tel	1000	3	0.5	INERT	365	2	1	5	1
307	HR X-ray									

MANIFESTING CODE INPUT

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KEY	SA03	T1 (up-dn)	2
TITLE 1	ASTROPHYSICS	T2 (on orb)	0
TITLE 2	FREE FLYER	T3 (use)	365
ALT	500	T4 IVA serv	0
INCL	29	T5 EVA serv	2
ΔV 1,2,3	0,0,0	T6 Msn Ops	72
DEL M	17	T7 Serv Freq	1
SUP M	0		
RET M	17	Beam L	0
DEL L	12	N. App	0
SUP L	0	N. Modules	0
DIA	4.2		
PWR	0		
INT VOL	0		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	FMXM		

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	0	1	0	0	0	0	-1	0	0	1	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
305	OPTEL	400	3	0.1	INERT	365	20			1
306	UVTEL (Starlab)	1800	10	2.2	INERT	365	10			1
314	Radio Tel	2000	3	0.1	INERT	365	20			1
315	Microwave Rec	80	2	0.2	INERT	365	2			1
316	Imag. Spect.	500	3	0.2	INERT	365	20			1
		4800	21	2.8	INERT	365	72			1

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	SA04
TITLE 1	ASTRO PHYSICS
TITLE 2	OBSERVATORIES
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	15
SUP M	4
RET M	15
DEL L	4
SUP L	4
DIA	4.2
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	FMXM

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	0
T5 EVA serv	6
T6 Msn Ops	0
T7 Serv Freq	1
Beam L	0
N. App	0
N. Modules	0

Traffic:

		90	91	92	93
		1	0	0	0
94	95	96	97	98	99
0	0	0	0	0	0
00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	Space Telescope									
	AXAF									
	GRO									

MANIFESTING CODE INPUT

KEY	CC01
TITLE 1	SSOS-CLASS
TITLE 2	COMSAT
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	7
SUP M	0
RET M	0
DEL L	4.5
SUP L	0
DIA	4
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	FXXX

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	0
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	0
T7 Serv Freq	0
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
6	6	6	6

94	95	96	97	98	99
6	8	8	8	8	8

00	01	02	03	04	05
8	8	8	8	8	8

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	SSOS-D+ 383									

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CC02	T1 (up-dn)	2
TITLE 1	INTELSAT-6A CLASS	T2 (on orb)	2
TITLE 2		T3 (use)	0
ALT	35786	T4 IVA serv	0
INCL	0	T5 EVA serv	0
ΔV 1,2,3	4300,4300,2000	T6 Msn Ops	0
DEL M	1.8	T7 Serv Freq	0
SUP M	0		
RET M	0	Beam L	0
DEL L	4	N. App	0
SUP L	0	N. Modules	0
DIA	4		
PWR	0		
INT VOL	0		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	FXXX		

Traffic:

		90	91	92	93
		0	1	1	1
94	95	96	97	98	99
1	1	0	0	0	0
00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CC03	T1 (up-dn)	2
TITLE 1	INTELSAT-7 CLASS	T2 (on orb)	2
TITLE 2		T3 (use)	0
ALT	35786	T4 IVA serv	0
INCL	0	T5 EVA serv	0
ΔV 1,2,3	4300,4300,2000	T6 Msn Ops	0
DEL M	5.0	T7 Serv Freq	0
SUP M	0		
RET M	0	Beam L	0
DEL L	6	N. App	4
SUP L	0	N. Modules	0
DIA	4.4		
PWR			
INT VOL			
POINT			
MANIF RESTR			
P/L CODE	FXCL		

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CC04
TITLE 1	MULTIBEAM COMM
TITLE 2	SATELLITE
ALT	35786
INCL	0.0
ΔV 1,2,3	4300,4300,2000
DEL M	5.0
SUP M	2.0
RET M	0
DEL L	8
SUP L	3
DIA	4.4
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SSCM

T1 (up-dn)	2
T2 (on orb)	2
T3 (use)	0
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	0
T7 Serv Freq	0
Beam L	4.4
N. App	10
N. Modules	2

Traffic:

90	91	92	93
0	0	0	0

94	95	96	97	98	99
0	1	1	1	1	0

00	01	02	03	04	05
0	1	1	0	1	1

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CC05	T1 (up-dn)	12
TITLE 1	RECONFIGURABLE	T2 (on orb)	7
TITLE 2	COMM SATELLITE	T3 (use)	7
ALT	35786	T4 IVA serv	3
INCL	0	T5 EVA serv	9
ΔV 1,2,3	4300,4300,2000	T6 Msn Ops	0
DEL M	1.8	T7 Serv Freq	1
SUP M	0.2		
RET M	0	Beam L	0
DEL L	4.4	N. App	2
SUP L	2	N. Modules	2
DIA	4		
PWR	0		
INT VOL	0		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	FXCM		

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	1	1	1	1	2	3	4	4	4	4	4	4	4	4	4

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

MANIFESTING CODE INPUT

KEY	CM05
TITLE 1	CONT FLOW ELEC-
TITLE 2	TROPH PLATFORM
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	7
SUP M	2
RET M	7
DEL L	6
SUP L	2
DIA	4.2
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	PMCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	60
T5 EVA serv	4
T6 Msn Ops	300
T7 Serv Freq	4

Beam L	0
N. App	0
N. Modules	1

Traffic:

90	91	92	93
1	0	0	1

94	95	96	97	98	99
0	0	1	0	0	0

00	01	02	03	04	05
1	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	Cont. Flow Electrophoresis									

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MANIFESTING CODE INPUT

KEY	CM06	T1 (up-dn)	2
TITLE 1	CONTINUOUS FLOW	T2 (on orb)	0
TITLE 2	ELECTROPHORESIS RESUP	T3 (use)	0
ALT	500	T4 IVA serv	12
INCL	28.5	T5 EVA serv	12
ΔV 1,2,3	0,0,0	T6 Msn Ops	12
DEL M	25	T7 Serv Freq	12
SUP M	2		
RET M	25	Beam L	0
DEL L	12	N. App	0
SUP L	2	N. Modules	0
DIA	4.2		
PWR	0		
INT VOL	0		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	PMCL		

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
1	4	4	5	7	9	11	12	14	16	17	20	20	20	20	20

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

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OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CM07
TITLE 1	GLASS PROC PLANT
TITLE 2	
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	15
SUP M	5
RET M	15
DEL L	10
SUP L	2
DIA	4.2
PWR	10.6
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SPCL

T1 (up-dn)	2
T2 (on orb)	-
T3 (use)	365
T4 IVA serv	90
T5 EVA serv	10
T6 Msn Ops	50
T7 Serv Freq	4
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	CM08	T1 (up-dn)	2
TITLE 1	GLASS PROCESSING	T2 (on orb)	
TITLE 2	OPTICAL FIBERS RESUP	T3 (use)	0
ALT	500	T4 IVA serv	8
INCL	28.5	T5 EVA serv	8
ΔV 1,2,3	0,0,0	T6 Msn Ops	8
DEL M	25	T7 Serv Freq	8
SUP M	2		
RET M	25	Beam L	0
DEL L	12	N. App	1
SUP L	2	N. Modules	2
DIA	4.2		
PWR	0		
INT VOL	0		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	SPCL		

Traffic:

90	91	92	93		
1	1	2	2		
94	95	96	97	98	99
2	3	3	4	5	6
00	01	02	03	04	05
8	10	12	15	15	15

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS
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MANIFESTING CODE INPUT

KEY	OT01
TITLE 1	LOW INCL STA
TITLE 2	MODULE DEL
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	22
SUP M	0
RET M	22
DEL L	14
SUP L	0
DIA	4.2
PWR	20
INT VOL	0
POINT	NONE
MANIF RESTR	3
P/L CODE	SSSS

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	0
T4 IVA serv	150
T5 EVA serv	10
T6 Msn Ops	0
T7 Serv Freq	0
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
0	1	1	1

94	95	96	97	98	99
0	0	0	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

MANIFESTING CODE INPUT

KEY	0T02
TITLE 1	LOW INCL STA
TITLE 2	RESUPPLY
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	15
SUP M	0
RET M	15
DEL L	8
SUP L	0
DIA	4.2
PWR	1
INT VOL	0
POINT	NONE
MANIF RESTR	3
P/L CODE	SORS

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	0
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	0
T7 Serv Freq	0
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
0	2	4	4

94	95	96	97	98	99
4	4	4	4	4	4

00	01	02	03	04	05
4	4	4	4	4	4

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

ORIGINAL PAGE IS OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	OT05
TITLE 1	HI ACT STA
TITLE 2	RESUP
ALT	500
INCL	29
ΔV 1,2,3	2985,1561,1761
DEL M	6
SUP M	0
RET M	5
DEL L	4
SUP L	0
DIA	4.2
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SORX

T1 (up-dn)	2
T2 (on orb)	5
T3 (use)	0
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	0
T7 Serv Freq	0
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
0	0	0	0

94	95	96	97	98	99
0	2	2	2	2	2

00	01	02	03	04	05
2	2	2	2	2	2

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

MANIFESTING CODE INPUT

KEY	TM01
TITLE 1	CONSTR, STORAGE,
TITLE 2	& HANGAR
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	2.0
SUP M	2.0
RET M	0
DEL L	2.5
SUP L	2
DIA	4.2
PWR	1.0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SPCM

T1 (up-dn)	2
T2 (on orb)	-
T3 (use)	-
T4 IVA serv	-
T5 EVA serv	-
T6 Msn Ops	10
T7 Serv Freq	1
Beam L	0
N. App	120
N. Modules	2

Traffic:

90	91	92	93
0	1	-1	0

94	95	96	97	98	99
0	0	0	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	Construction &	2037								
	Storage Facility Hangar	2034								
	Delivery & Assy & Test									

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	TP01	T1 (up-dn)	4
TITLE 1	Prop Transfer	T2 (on orb)	0
TITLE 2	& Storage	T3 (use)	20
ALT	500	T4 IVA serv	0
INCL	30	T5 EVA serv	0
ΔV 1,2,3	0,0,0	T6 Msn Ops	10
DEL M	10	T7 Serv Freq	1
SUP M	0.5		
RET M	3	Beam L	0
DEL L	7	N. App	0
SUP L	0.5	N. Modules	1
DIA	4.2		
PWR	1		
INT VOL	0		
POINT	NONE		
MANIF RESTR	3.		
P/L CODE	SPCL		

Traffic:

90	91	92	93
0	0	1	-1

94	95	96	97	98	99
0	0	0	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2063									
	2064									

ORIGINAL PAGE IS
OF POOR QUALITY

MANIFESTING CODE INPUT

KEY	TP02
TITLE 1	OTV MAINT TECH
TITLE 2	DEMO
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	3.6
SUP M	2
RET M	3.6
DEL L	10.9
SUP L	2.5
DIA	4.2
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SSCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	20
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	10
T7 Serv Freq	1
Beam L	0
N. App	0
N. Modules	1

Traffic:

90	91	92	93
0	0	0	1

94	95	96	97	98	99
-1	0	0	0	0	0

00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2066									
	2065									
	2067									

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MANIFESTING CODE INPUT

KEY	TS01	T1 (up-dn)	2
TITLE 1	SATELLITE ASSY	T2 (on orb)	0
TITLE 2	& SERVICE	T3 (use)	90
ALT	500	T4 IVA serv	0
INCL	29	T5 EVA serv	0
ΔV 1,2,3	0,0,0	T6 Msn Ops	90
DEL M	2.6	T7 Serv Freq	1
SUP M	2		
RET M	2.6	Beam L	0
DEL L	7.9	N. App	0
SUP L	2.5	N. Modules	1
DIA	4.2		
PWR	0		
INT VOL	0		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	SSCL		

<u>Traffic:</u>

90	91	92	93		
0	0	0	0		
94	95	96	97	98	99
1	-1	0	0	0	0
00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM		MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2071	Satellite Assy Tech Demo									
	2072	On-Board Sat Serv Tech Demo									
	2070	Formation Flying Tech Demo									

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MANIFESTING CODE INPUT

KEY	TE01
TITLE 1	LARGE POWER SYS
TITLE 2	TECHNOLOGY
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	1.2
SUP M	0.1
RET M	1.2
DEL L	2
SUP L	2
DIA	4.2
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SSCL

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	80
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	80
T7 Serv Freq	1
Beam L	0
N. App	0
N. Modules	2

Traffic:

90	91	92	93		
0	0	0	0		
94	95	96	97	98	99
0	1	-1	0	0	0
00	01	02	03	04	05
0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2020									
	2024									

MANIFESTING CODE INPUT

KEY	TC01
TITLE 1	ROBOTICS
TITLE 2	TECH DEMO
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	3.6
SUP M	0.5
RET M	3.6
DEL L	1.8
SUP L	0.1
DIA	1.0
PWR	3.0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	SSCM

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	90
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	90
T7 Serv Freq	1
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	0	0	0	0	0	0	1	-1	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2075									
	2073									

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MANIFESTING CODE INPUT

KEY	TM02
TITLE 1	PRECISION OPT
TITLE 2	CONSTR & TEST
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	5.0
SUP M	2.0
RET M	5.0
DEL L	5
SUP L	2
DIA	4.2
PWR	0.5
INT VOL	0
POINT	INERT
MANIF RESTR	0
P/L CODE	SPCH

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	50
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	50
T7 Serv Freq	1
Beam L	0
N. App	7
N. Modules	82

Traffic:

		90	91	92	93
		0	0	0	0
94	95	96	97	98	99
0	0	0	0	0	0
00	01	02	03	04	05
1	-1	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2036									

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MANIFESTING CODE INPUT

KEY	TM03
TITLE 1	PASSIVE MICROWAVE
TITLE 2	RADIOMETER
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	3
SUP M	3
RET M	3
DEL L	13
SUP L	2.5
DIA	4.2
PWR	0.5
INT VOL	0
POINT	EARTH
MANIF RESTR	0
P/L CODE	SPCM

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	148
T4 IVA serv	0
T5 EVA serv	0
T6 Msn Ops	148
T7 Serv Freq	0
Beam L	0
N. App	252
N. Modules	3

Traffic:

		90	91	92	93
		0	0	0	0
94	95	96	97	98	99
0	0	0	0	0	0
00	01	02	03	04	05
0	0	1	-1	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2001									

MANIFESTING CODE INPUT

KEY	TE02	T1 (up-dn)	2
TITLE 1	LIQ DROPLET	T2 (on orb)	0
TITLE 2	RADIATOR	T3 (use)	20
ALT	500	T4 IVA serv	0
INCL	29	T5 EVA serv	0
ΔV 1,2,3	0,0,0	T6 Msn Ops	20
DEL M	3.6	T7 Serv Freq	1
SUP M	0.5		
RET M	3.6	Beam L	0
DEL L	10.0	N. App	0
SUP L	1.0	N. Modules	0
DIA	2		
PWR	1.0		
INT VOL	0		
POINT	INERT		
MANIF RESTR	0		
P/L CODE	SPCL		

Traffic:

90	91	92	93		
0	0	0	0		
94	95	96	97	98	99
0	0	0	0	0	0
00	01	02	03	04	05
0	0	0	0	0	1

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2011									

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MANIFESTING CODE INPUT

KEY	TS01	T1 (up-dn)	2
TITLE 1	TECH DEVEL	T2 (on orb)	0
TITLE 2	CARRY-ONS	T3 (use)	25
ALT	500	T4 IVA serv	5
INCL	29	T5 EVA serv	5
ΔV 1,2,3	0,0,0	T6 Msn Ops	20
DEL M	0.5	T7 Serv Freq	0
SUP M	0		
RET M	0.5	Beam L	0
DEL L	0.1	N. App	0
SUP L	0.1	N. Modules	0
DIA	0		
PWR	0.5		
INT VOL	2.0		
POINT	NONE		
MANIF RESTR	0		
P/L CODE	SSSA		

Traffic:

90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.
	2059									
	2013									
	2014									
	2060									
	2061									
	2068									
	2018									
	2069									
	2029									
	2035									
	2009									
	2027									
	2012									
	2006									
	2074									
	2019									

MANIFESTING CODE INPUT

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KEY	SA05
TITLE 1	LARGE RADIO
TITLE 2	TELESCOPE
ALT	500
INCL	29
ΔV 1,2,3	0,0,0
DEL M	5
SUP M	5
RET M	5
DEL L	7
SUP L	3
DIA	4.2
PWR	0
INT VOL	0
POINT	NONE
MANIF RESTR	0
P/L CODE	FMCH

T1 (up-dn)	2
T2 (on orb)	0
T3 (use)	365
T4 IVA serv	5
T5 EVA serv	5
T6 Msn Ops	5
T7 Serv Freq	1
Beam L	0
N. App	0
N. Modules	0

Traffic:

90	91	92	93
0	0	0	0

94	95	96	97	98	99
0	0	0	0	0	0

00	01	02	03	04	05
1	0	0	0	0	0

PAYLOADS/INSTR INCLUDED

#	ITEM	MASS	VOL	PWR	POINT	USE	IVA	EVA	MSN	S.F.

0002

APPENDIX 5

PAYLOAD POINTING REQUIREMENTS

APPENDIX 5-1

MISSION DRIVEN SCENARIO
PAYLOAD POINTING REQUIREMENTS

```
         ***POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION***
       EARTH: @                NONE: -                 INERTIAL: *
                                      DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3              1990
          2    5    7    0    2    5    7    0    2    5    7    0    2    5
     0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

SA04  ---------------------------------------------------------------------------

CM05  ---------------------------------------------------------------------------

CM06                                      -

OT01                                      -

OT02                                      -
```

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: @ NONE: - INERTIAL: *

DAYS/YEAR

0 25 50 75 100 125 150 175 200 225 250 275 300 325 350

1990

```
***POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION***

EARTH: @                NONE: -                 INERTIAL: *
                              DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3
          2    5    7    0    2    5    7    0    2    5    7    0    2    5
     0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
SL01 -------------------------------------------------------------------------
SA02 *************************************************************************
SA04 -------------------------------------------------------------------------
CC05                                    -
CM05 -------------------------------------------------------------------------
CM06                                    -
OT01                                    -
OT02                                    -
TM01                                    -
TS01                                  -----
```

1991

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ●　　NONE: -　　INERTIAL: *

DAYS/YEAR

1991

				1	1	1	1	2	2	2	2	3	3	3
	2	5	7	0	2	5	7	0	2	5	7	0	2	5
0	5	0	5	0	5	0	5	0	5	0	5	0	5	0

OT03　-

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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

1992

```
                           1    1    1    1    2    2    2    2    3    3    3
            2    5    7    0    2    5    7    0    2    5    7    0    2    5
       0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
SL01   -----------------------------------------------------------------------
CM01                            --------------------------
SA02   ***********************************************************************
SA04   -----------------------------------------------------------------------
CC05                                        -
CM05   -----------------------------------------------------------------------
CM06                                        -
CM07   -----------------------------------------------------------------------
CM08                                        -
OT01                                        -
OT02                                        -
TP01                                     ----
TS01                                    -----
```

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```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***

    EARTH: @                NONE: -                 INERTIAL: *
                                  DAYS/YEAR

                            1    1    1    1    2    2    2    2    3    3    3
             2    5    7    0    2    5    7    0    2    5    7    0    2    5
        0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

OT03                                     -

OT04                                     -

SP01      --------------------------------------------------------------------------

SA01      **************************************************************************
```

1992

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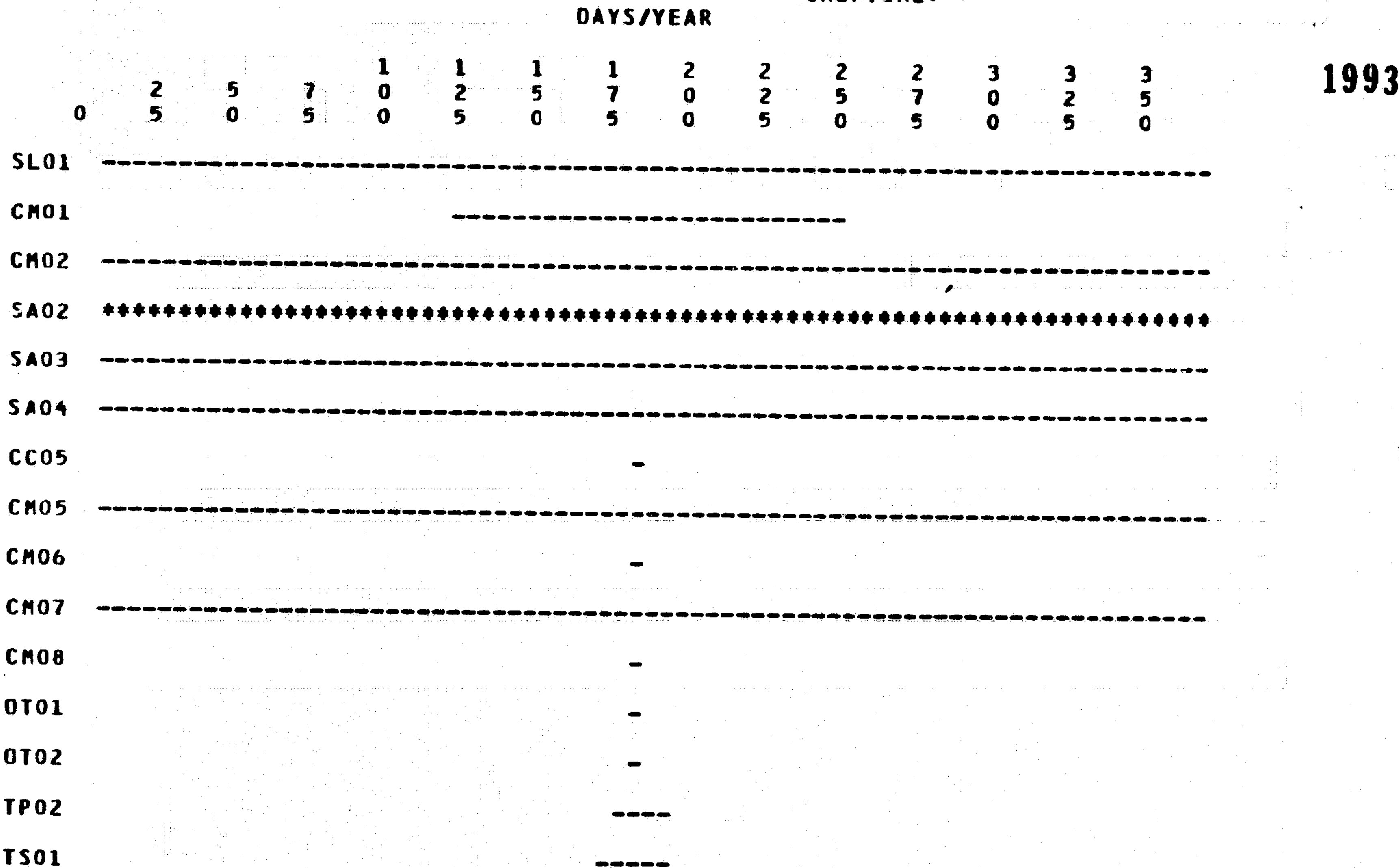
POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: – INERTIAL: *



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```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***

     EARTH: @                 NONE: -                 INERTIAL: *
                                    DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3
          2    5    7    0    2    5    7    0    2    5    7    0    2    5          1993
     0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@

OT03                                       -

OT04                                       -

SP01  -------------------------------------------------------------------------

SP02 @@@@@@@

SA01  *************************************************************************
```

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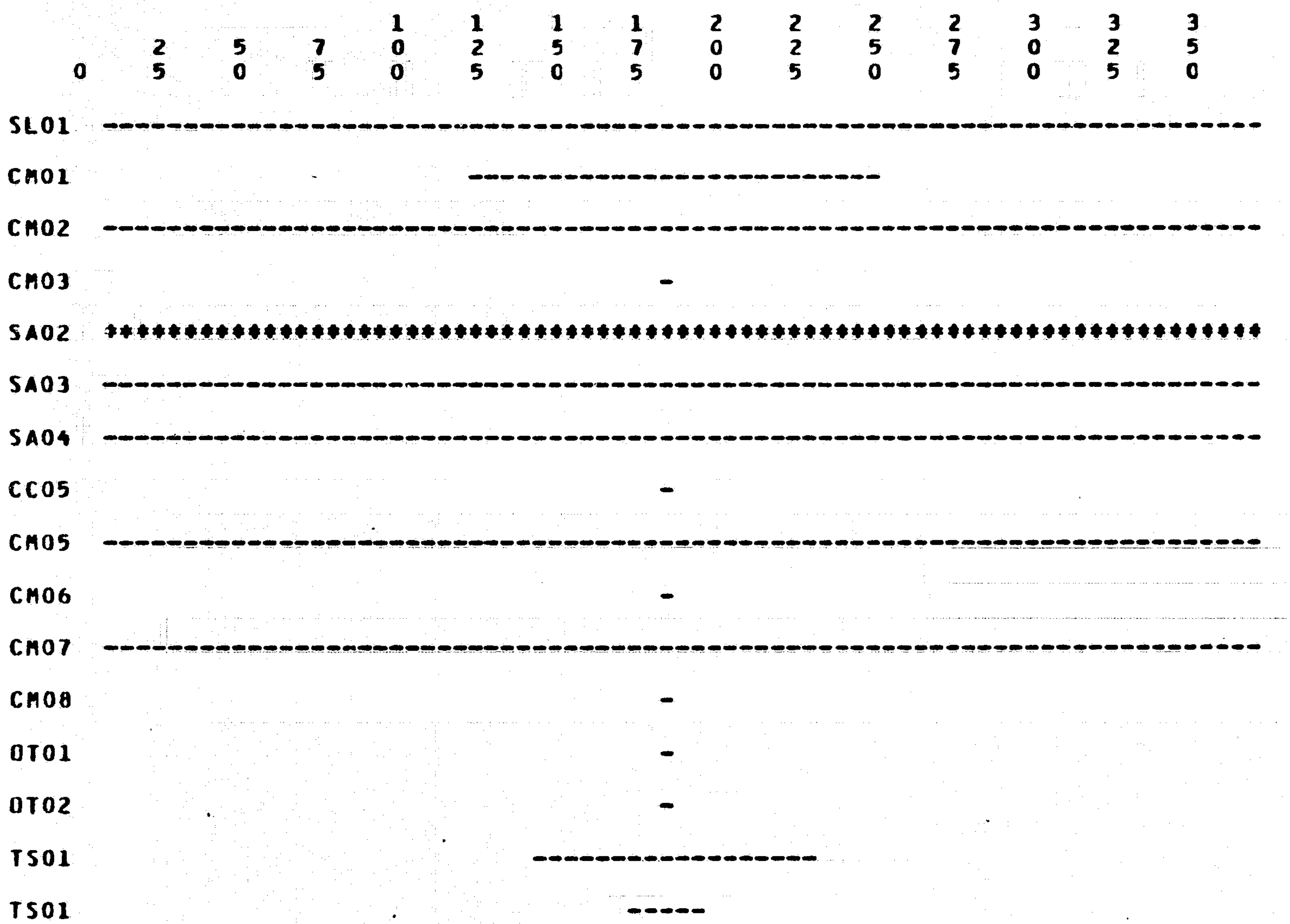
POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: – INERTIAL: *

DAYS/YEAR

1994



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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

```
                        1    1    1    1    2    2    2    2    3    3    3
         2    5    7    0    2    5    7    0    2    5    7    0    2    5          1994
    0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OT03                                     -

OT04                                     -

SP02 ●●●●●●●

SA01  *************************************************************************
```

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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION

EARTH: ●   NONE: -   INERTIAL: *

DAYS/YEAR

1995

```
                      1   1   1   1   2   2   2   2   3   3   3
          2   5   7   0   2   5   7   0   2   5   7   0   2   5
      0   5   0   5   0   5   0   5   0   5   0   5   0   5   0
SL01   ---------------------------------------------------------
CM01                     ----------------------
CM02   ---------------------------------------------------------
CM03                                 -
SA02   *********************************************************
SA03   ---------------------------------------------------------
SA04   ---------------------------------------------------------
CC03                                 -
CC04                                 -
CC05                                 -
CM05   ---------------------------------------------------------
CM06                                 -
CM07   ---------------------------------------------------------
CM08                                 -
OT01                                 -
OT02                                 -
OT05                                 -
TE01                       -------------
TS01                           ----
```

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```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***
  EARTH: ●                      NONE: -                INERTIAL: *
                                       DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3
         2    5    7     0    2    5    7    0    2    5    7    0    2    5
    0    5    0    5     0    5    0    5    0    5    0    5    0    5    0
S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
S002 ●●
OT03                                     -
OT04                                     -
SP02 ●●●●●●●
SA01 **************************************************************************
```

1995

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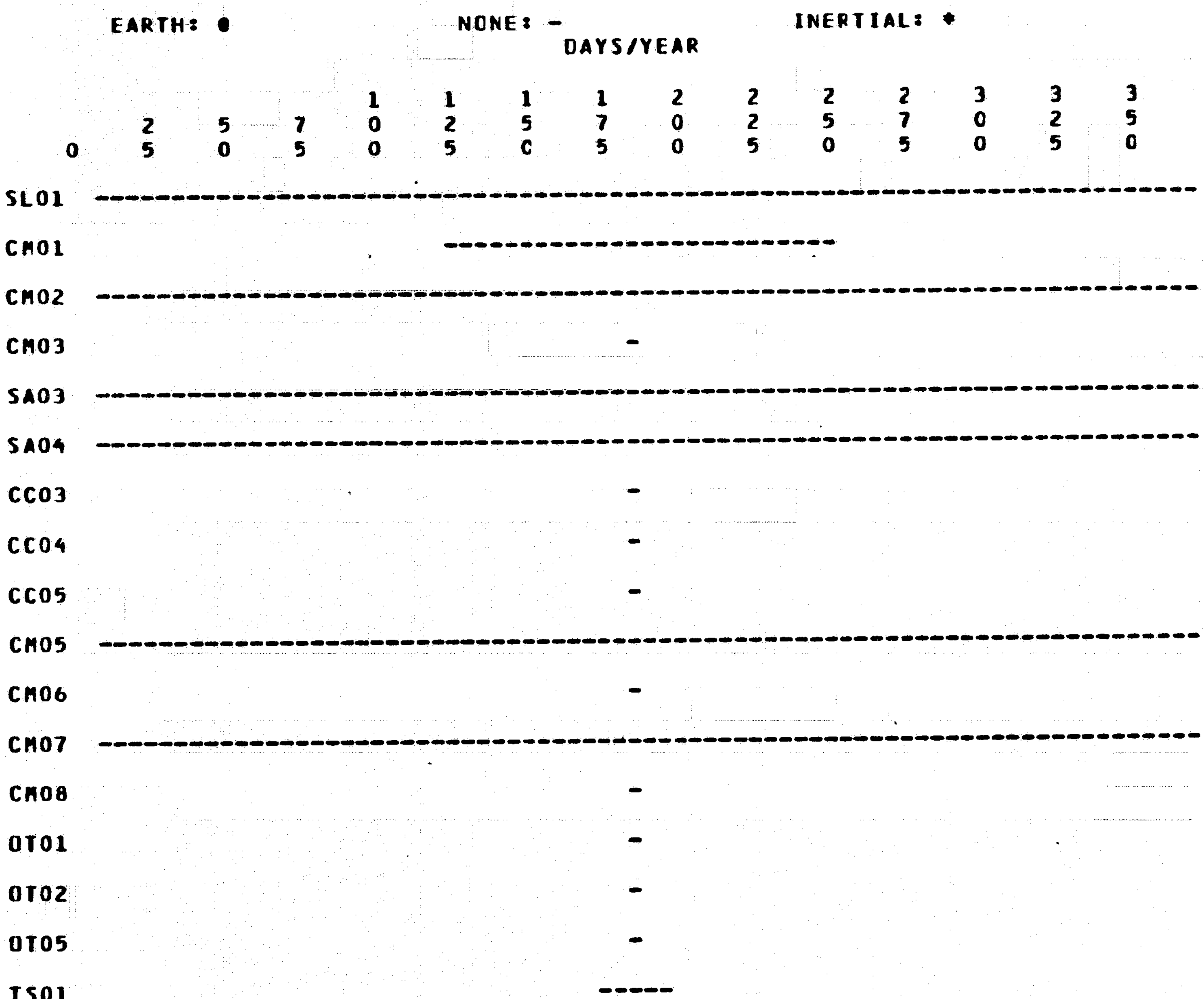
POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

1996



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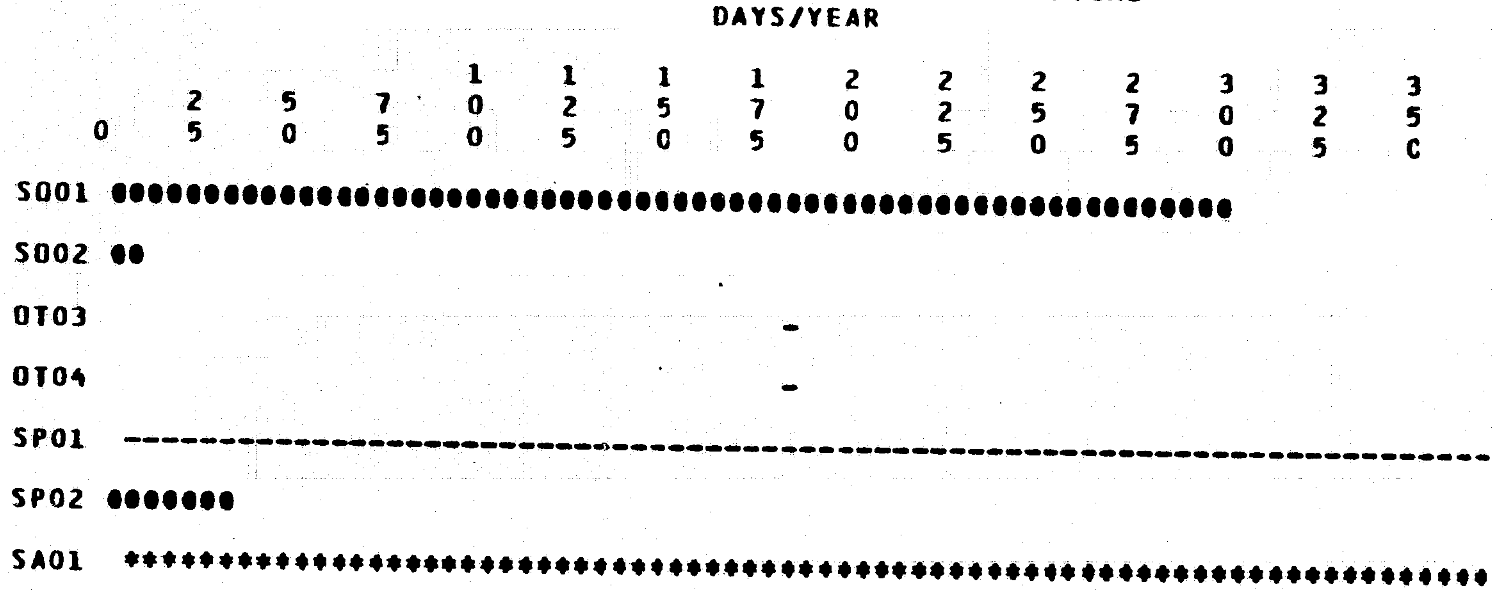
POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ●   NONE: -   INERTIAL: *

1996



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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: @   NONE: -   INERTIAL: *

DAYS/YEAR

1997

```
                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
SL01   ------------------------------------------------------------------------
CM01                          ---------------------------
CM02   ------------------------------------------------------------------------
CM03                                      -
CM04                                      -
SA03   ------------------------------------------------------------------------
SA04   ------------------------------------------------------------------------
CC03                                      -
CC04                                      -
CC05                                      -
CM05   ------------------------------------------------------------------------
CM06                                      -
CM07   ------------------------------------------------------------------------
CM08                                      -
OT01                                      -
OT02                                      -
OT05                                      -
TC01                              ------------------
TS01                                    -----
```

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```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***

     EARTH: ●                NONE: -                 INERTIAL: *
                                     DAYS/YEAR

                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

S002 ●●

S004 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OT03                                    -

OT04                                    -

SP01  -------------------------------------------------------------------------

SA01  *************************************************************************

SL08  -------------------------------------------------------------------------
```

1997

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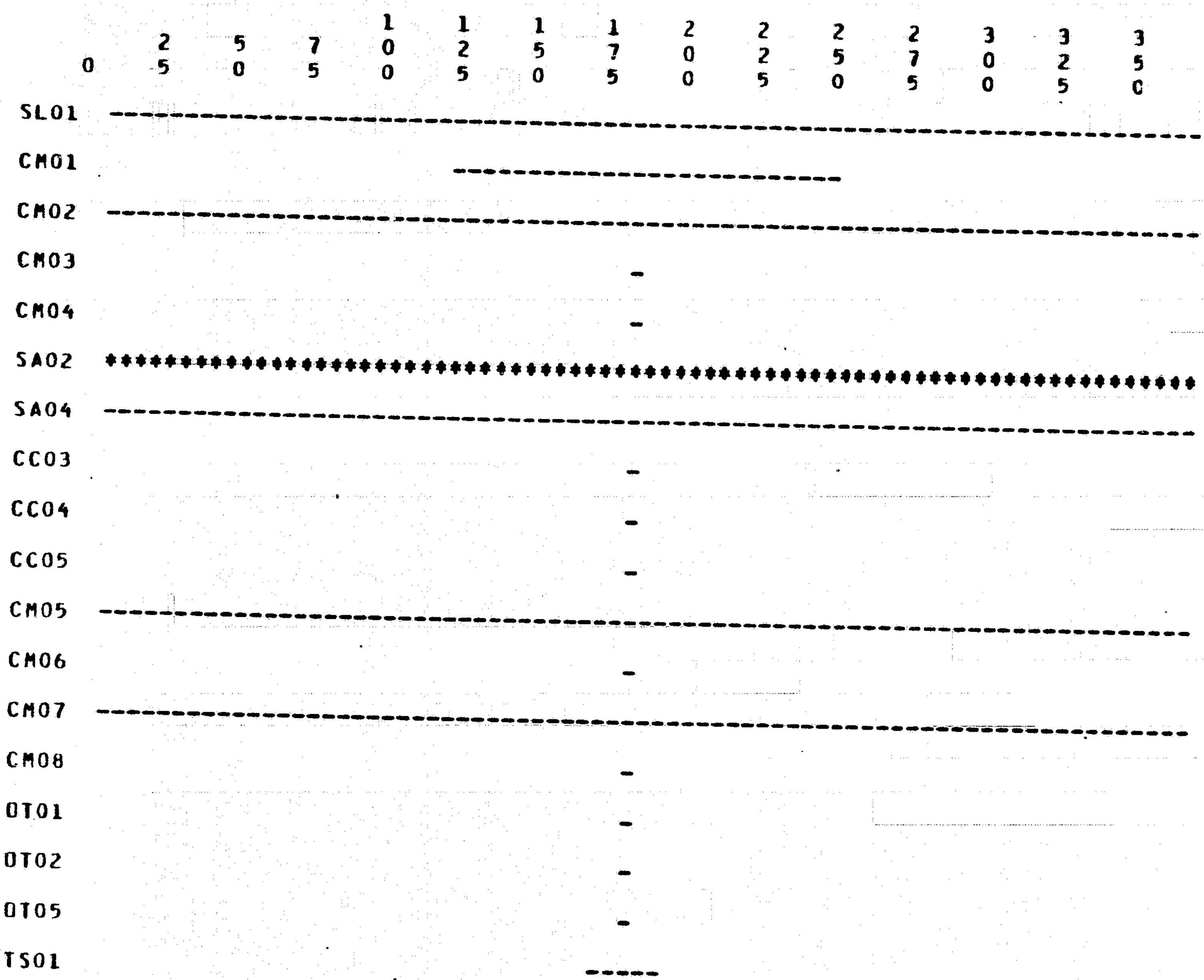
POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: – INERTIAL: *

DAYS/YEAR



1998

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```
     ***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***

   EARTH: ●                    NONE: -                    INERTIAL: *
                                     DAYS/YEAR

                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001  ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

S002  ●●

S003  ●●●●●●●●●●

S004  ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OT03                                       -

OT04                                       -

SP01  --------------------------------------------------------------------------

SA01  **************************************************************************

SL08  --------------------------------------------------------------------------
```

1998

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```
   ***POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION***
  EARTH: ●                  NCNE: -                 INERTIAL: *
                                   DAYS/YEAR
                                                                                    1999
                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    C
SL01    -------------------------------------------------------------------------
CM01                          ---------------------------
CM02    -------------------------------------------------------------------------
CM03                                       -
CM04                                       -
SA02    *************************************************************************
SA04    -------------------------------------------------------------------------
CC03                                       -
CC04                                       -
CC05                                       -
CM05    -------------------------------------------------------------------------
CM06                                       -
CM07    -------------------------------------------------------------------------
CM08                                       -
OT01                                       -
OT02                                       -
OT05                                       -
TS01                                    -----
```

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

```
     EARTH: ●              NONE: -              INERTIAL: *
                                 DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3
          2    5    7    0    2    5    7    0    2    5    7    0    2    5
     0    5    0    5    0    5    C    5    0    5    0    5    0    5    C      1999

S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

S002 ●●

S003 ●●●●●●●●●●

S004 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OT03                                     -

OT04                                     -

SA01  *************************************************************************

SL08  -------------------------------------------------------------------------
```

ORIGINAL PAGE IS
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```
***POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION***

   EARTH: @                  NONE: -                  INERTIAL: *
                                      DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3
          2    5    7    0    2    5    7    0    2    5    7    0    2    5        2000
     0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
CM01                          --------------------------
CM02  --------------------------------------------------------------------------
CM03                                      -
CM04                                      -
SA02  **************************************************************************
SA04  --------------------------------------------------------------------------
CC03                                      -
CC04                                      -
CC05                                      -
CM05  --------------------------------------------------------------------------
CM06                                      -
CM07  --------------------------------------------------------------------------
CM08                                      -
OT01                                      -
OT02                                      -
OT05                                      -
TM02                                                                  **********
TS01                                   -----
SA05  --------------------------------------------------------------------------
```

ORIGINAL PAGE IS
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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ●   NONE: -   INERTIAL: *

DAYS/YEAR

2000

```
                        1    1    1    1    2    2    2    2    3    3    3
         2    5    7    0    2    5    7    0    2    5    7    0    2    5
    0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

S002 ●●

S003 ●●●●●●●●●●

S004 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OT03                                     -

OT04                                     -

SP02 ●●●●●●●

SA01  *************************************************************************
```

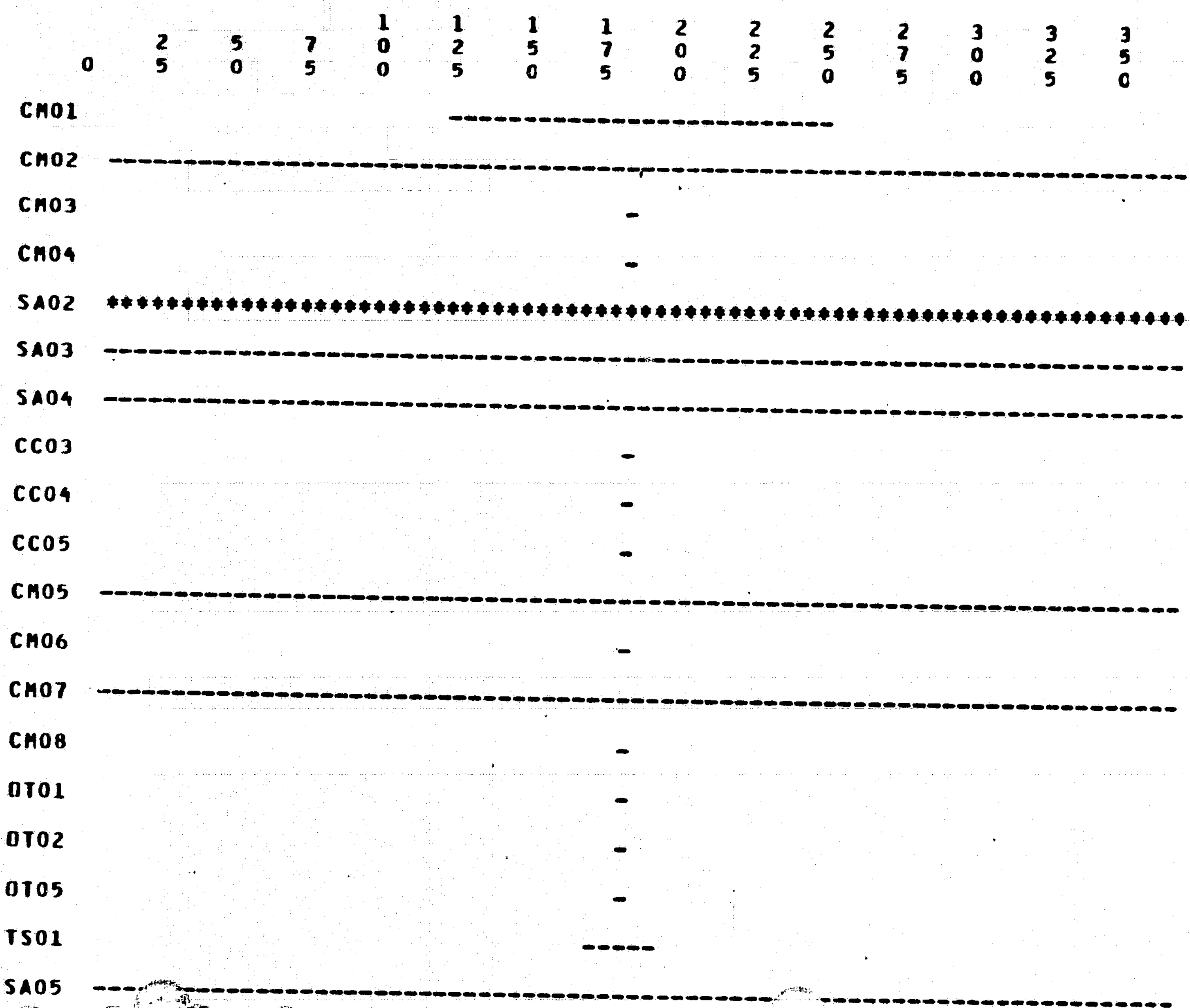
ORIGINAL PAGE IS OF POOR QUALITY

POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

2001



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***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***

   EARTH: ●                        NONE: -                        INERTIAL: *
                                       DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3
          2    5    7    0    2    5    7    0    2    5    7    0    2    5
     0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

S002 ●●

S003 ●●●●●●●●●●

S004 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OT03                                        -

OT04                                        -

SP02 ●●●●●●●

SA01  *************************************************************************
```

2001

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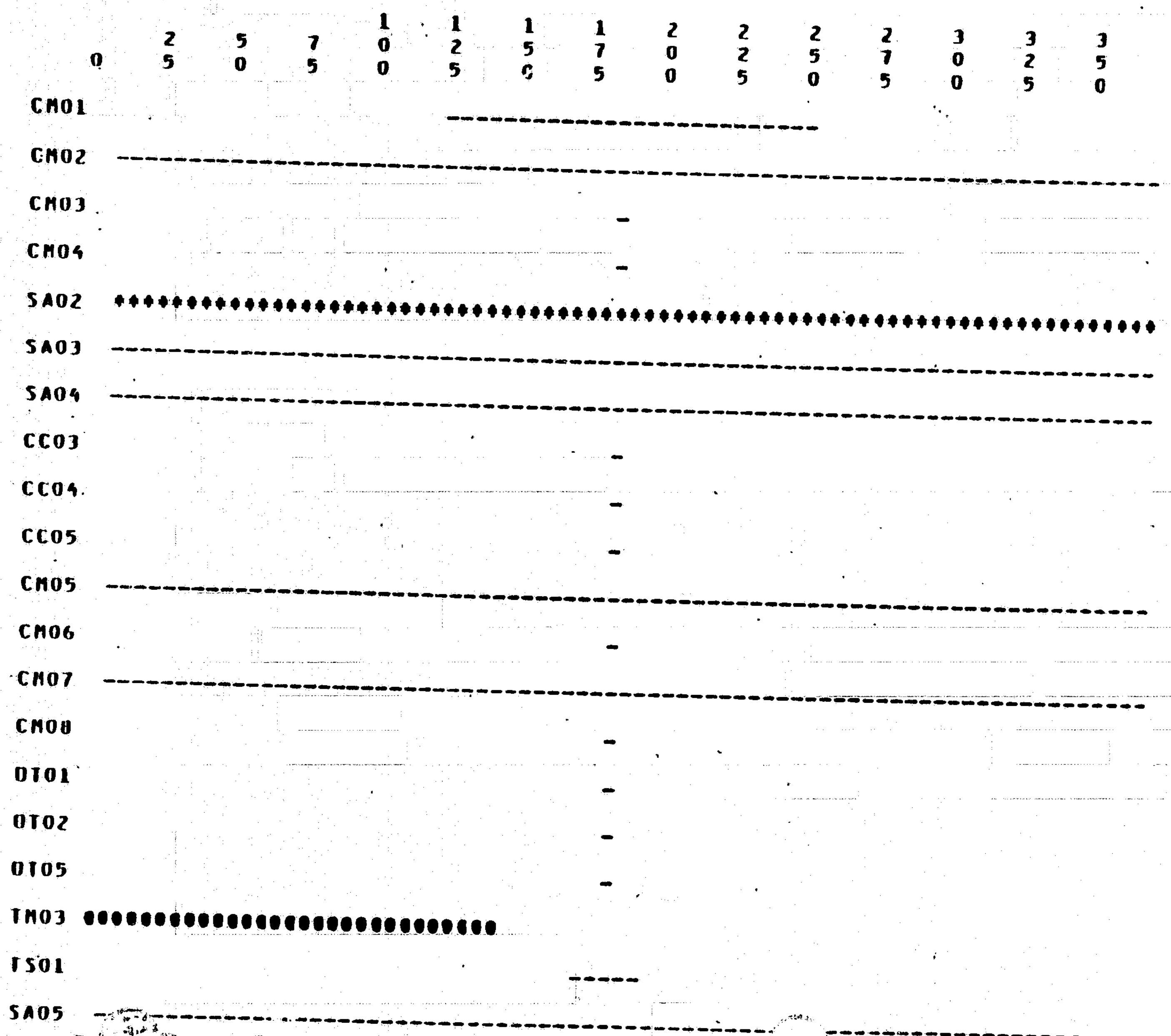
POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: – INERTIAL: ♦

DAYS/YEAR

2002



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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

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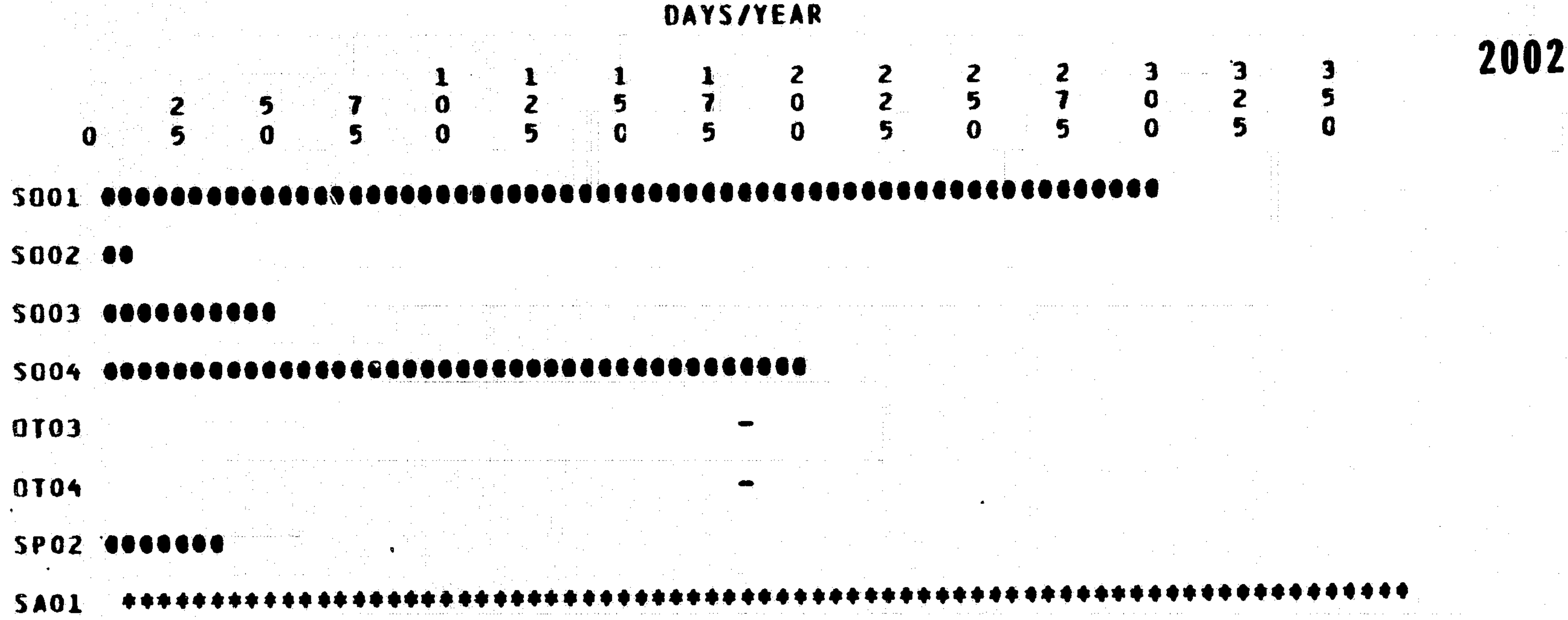
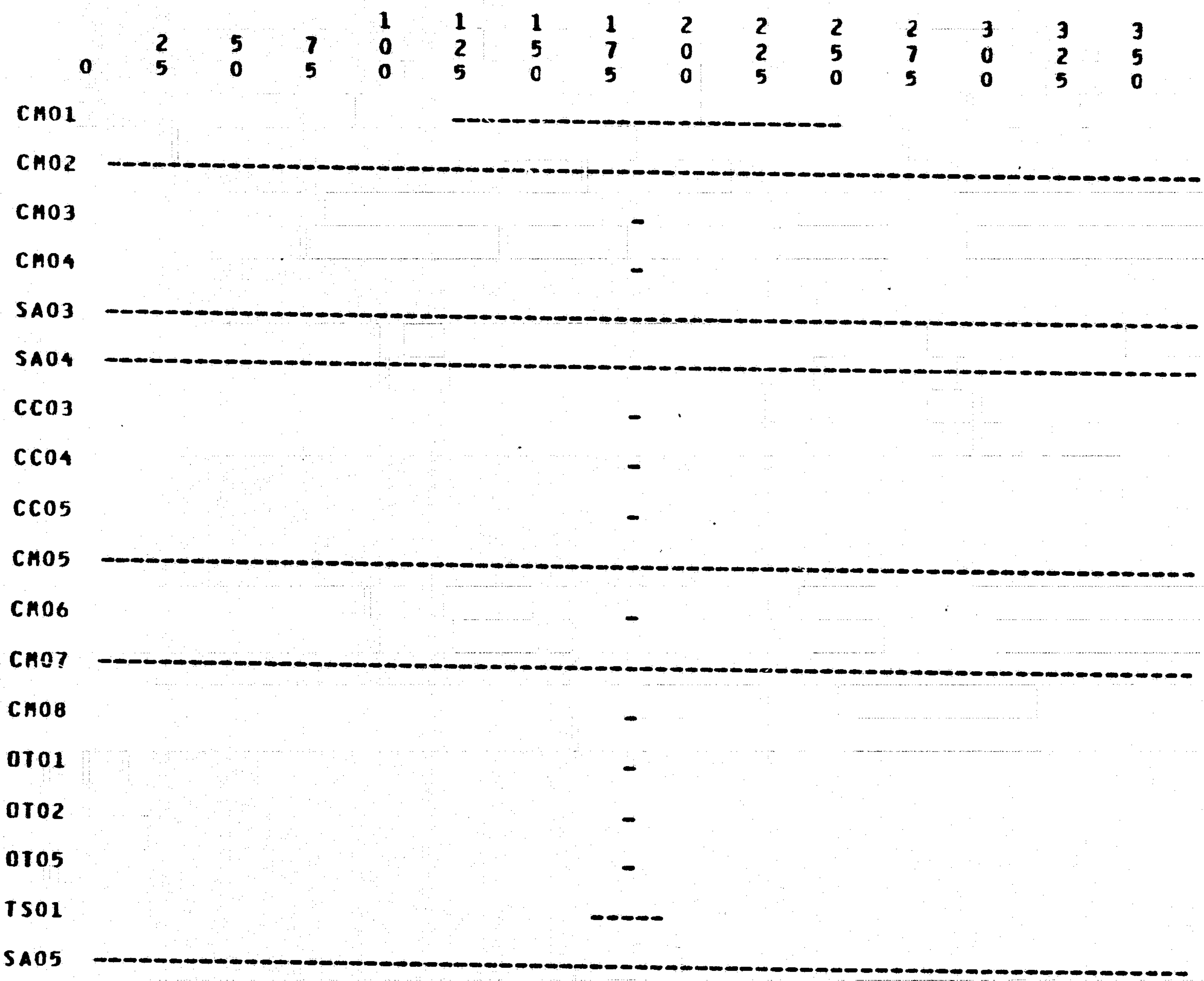


POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: – INERTIAL: *

DAYS/YEAR

2003



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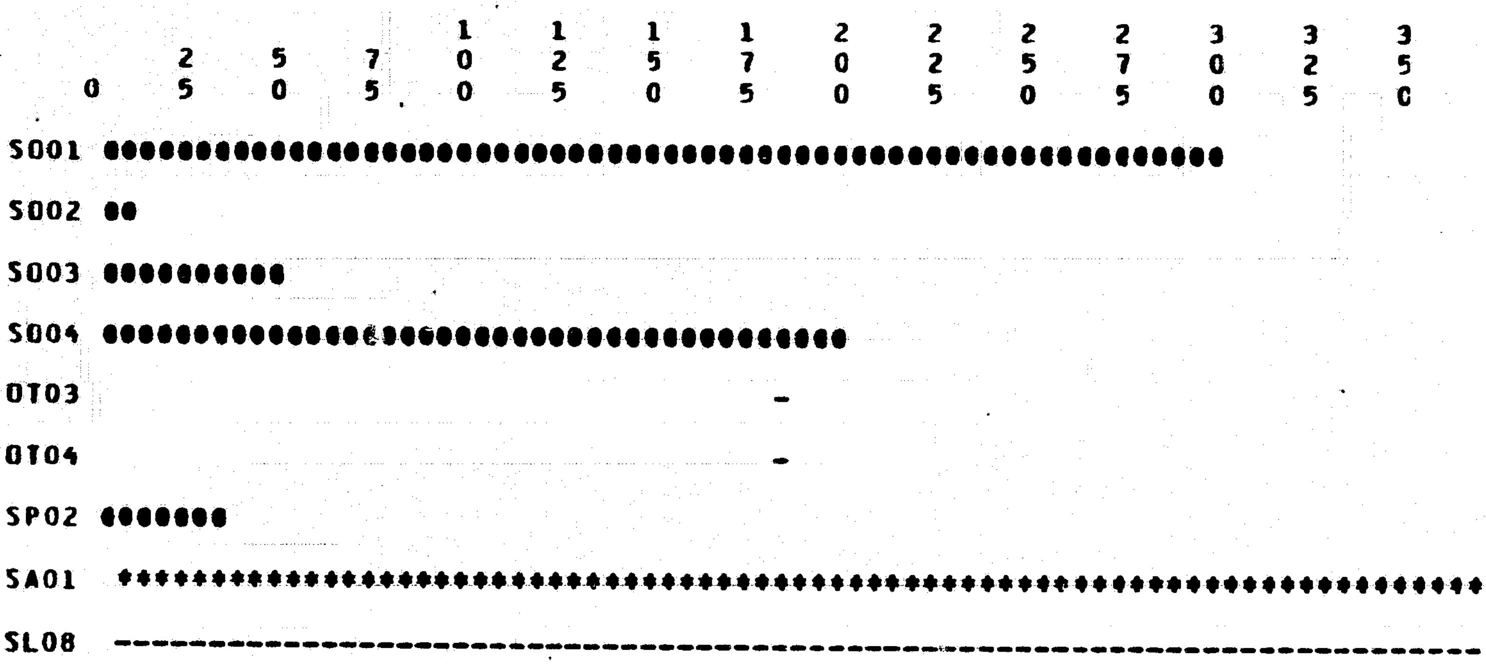
POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ●   NONE: –   INERTIAL: *

DAYS/YEAR

2003

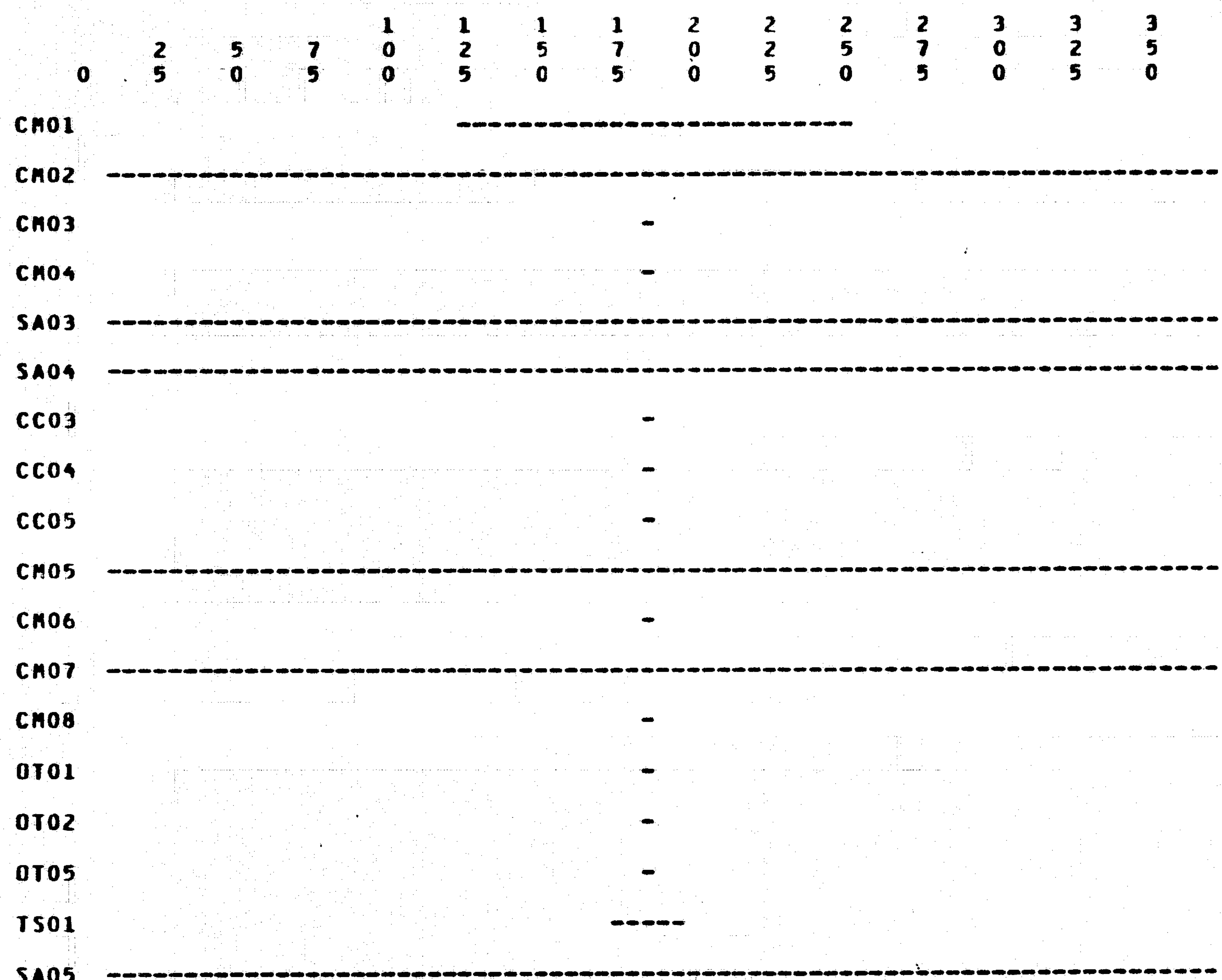


POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

2004



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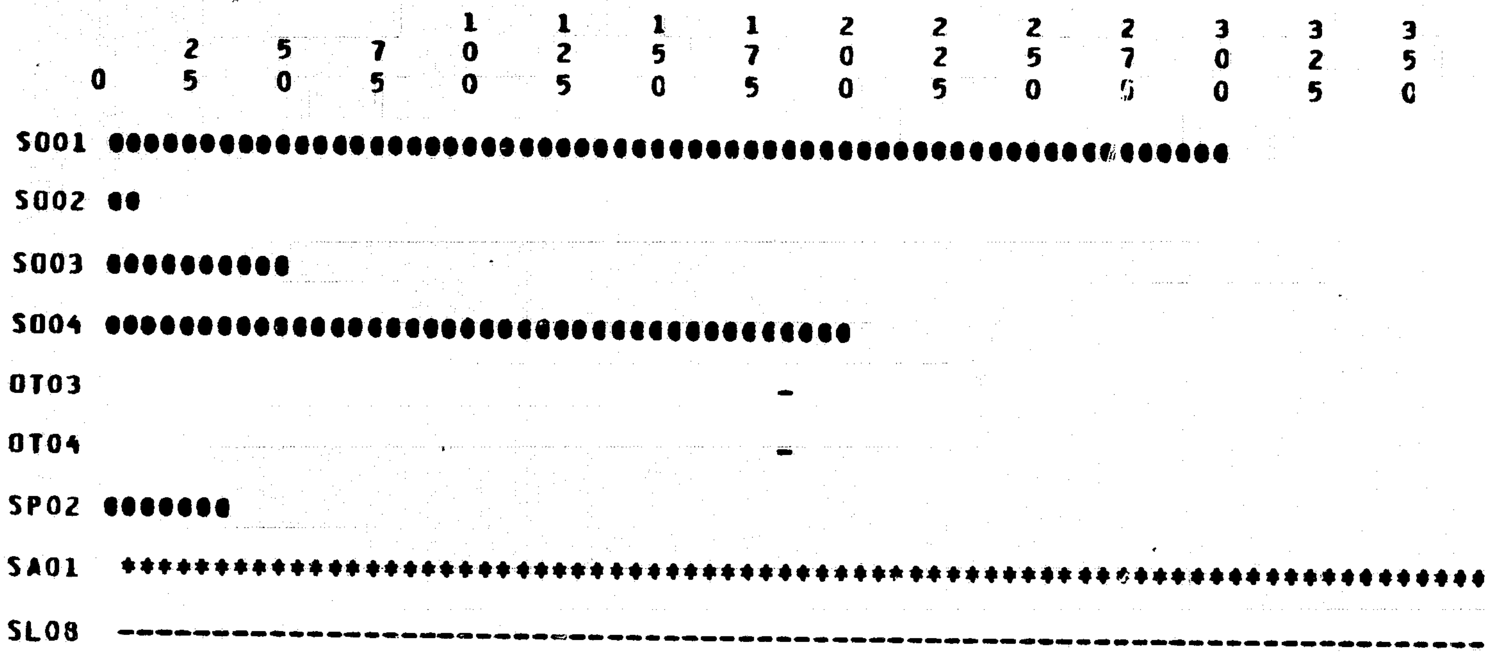
POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: – INERTIAL: *

DAYS/YEAR

2004



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        ***POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION***
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                                   DAYS/YEAR
                           1    1    1    1    2    2    2    2    3    3    3
            2    5    7    0    2    5    7    0    2    5    7    0    2    5
       0    5    0    5    0    5    0    5    0    5    0    5    0    5    C
CM01                           ---------------------------
CM02    ---------------------------------------------------------------------------
CM03                                       -
CM04                                       -
SA03    --------------------------------------------------------------------------
SA04    --------------------------------------------------------------------------
CC03                                       -
CC04                                       -
CC05                                       -
CM05    --------------------------------------------------------------------------
CM06                                       -
CM07    --------------------------------------------------------------------------
CM08                                       -
OT01                                       -
OT02                                       -
OT05                                       -

TE02                                                                          ****
TS01                                     -----
SA05    ---------------------------------------------------------------------------
```

2005

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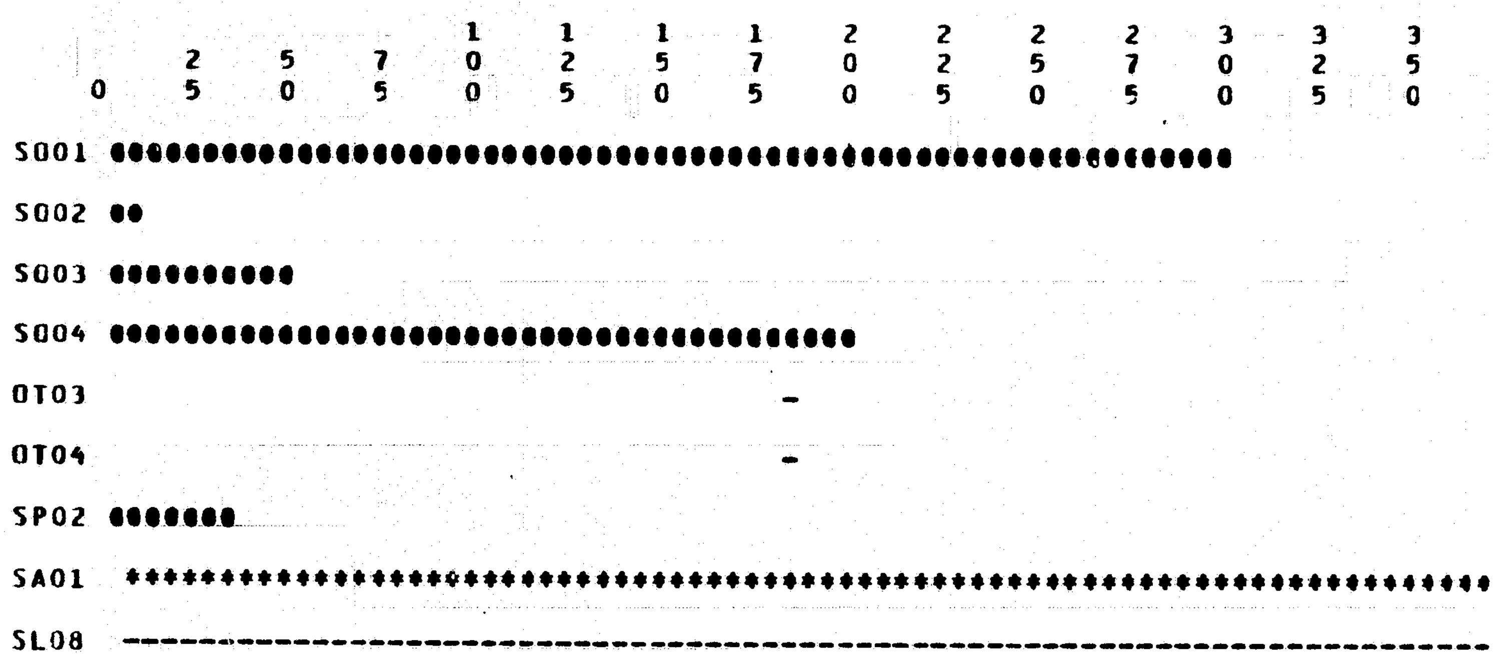
POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

2005



APPENDIX 5-2

STATION CONSTRAINED SCENARIO PAYLOAD POINTING REQUIREMENTS

POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ●   NONE: -   INERTIAL: *

DAYS/YEAR

1990

0	25	50	75	100	125	150	175	200	225	250	275	300	325	350

0T01 -

POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

0 25 50 75 100 125 150 175 200 225 250 275 300 325 350

1990

POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

1991

	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350
OT01								-							
OT02								-							
TM01								-							
TS01								-----							

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

				1	1	1	1	2	2	2	2	3	3	3	
	2	5	7	0	2	5	7	0	2	5	7	0	2	5	1991
0	5	0	5	0	5	0	5	0	5	0	5	0	5	0	

POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION

EARTH: ●   NONE: -   INERTIAL: *

DAYS/YEAR

```
                        1    1    1    1    2    2    2    2    3    3    3          1992
         2    5    7    0    2    5    7    0    2    5    7    0    2    5
    0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
CM01                         --------------------------
SA04  ------------------------------------------------------------------------
OT01                                     -
OT02                                     -
TP01                                    ----
TS01                                   -----
```

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

1992

				1	1	1	1	2	2	2	2	3	3	3
	2	5	7	0	2	5	7	0	2	5	7	0	2	5
0	5	0	5	0	5	0	5	0	5	0	5	0	5	0

```
***POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION***

  EARTH: @                  NONE: -                   INERTIAL: *
                                  DAYS/YEAR
                                                                              1993
                         1    1    1    1    2    2    2    2    3    3    3
          2    5    7    0    2    5    7    0    2    5    7    0    2    5
     0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
CM01                         ---------------------------
CM02  --------------------------------------------------------------------------
SA03  --------------------------------------------------------------------------
SA04  --------------------------------------------------------------------------
CM05  --------------------------------------------------------------------------
CM06                                     -
OT01                                     -
OT02                                     -
TP02                                    ----
TS01                                   -----
```

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

0	25	50	75	100	125	150	175	200	225	250	275	300	325	350

1993

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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

1994

```
                                  DAYS/YEAR

                        1    1    1    1    2    2    2    2    3    3    3
         2    5    7    0    2    5    7    0    2    5    7    0    2    5
    0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

CM01                         --------------------------
CM02  -------------------------------------------------------------------------
CM03                                     -
SA03  -------------------------------------------------------------------------
SA04  -------------------------------------------------------------------------
CM05  -------------------------------------------------------------------------
CM06                                     -
OT01                                     -
OT02                                     -
TS01                             ------------------
TS01                                   -----
```

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ●   NONE: –   INERTIAL: *

DAYS/YEAR

1994

```
                    1   1   1   1   2   2   2   2   3   3   3
    2   5   7   0   2   5   7   0   2   5   7   0   2   5
0   5   0   5   0   5   0   5   0   5   0   5   0   5   0
```

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```
***POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION***

EARTH: @               NONE: -               INERTIAL: *
                           DAYS/YEAR

                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5          1995
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

CM01                               --------------------------
CM02    -------------------------------------------------------------------------
CM03                                           -
SA02    *************************************************************************
SA03    -------------------------------------------------------------------------
SA04    -------------------------------------------------------------------------
CM05    -------------------------------------------------------------------------
CM06                                           -
OT01                                           -
OT02                                           -
TE01                                    ----------------
TS01                                        -----
```

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: @ NONE: - INERTIAL: *

DAYS/YEAR

1995

	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350
OT03								-							
OT04								-							

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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

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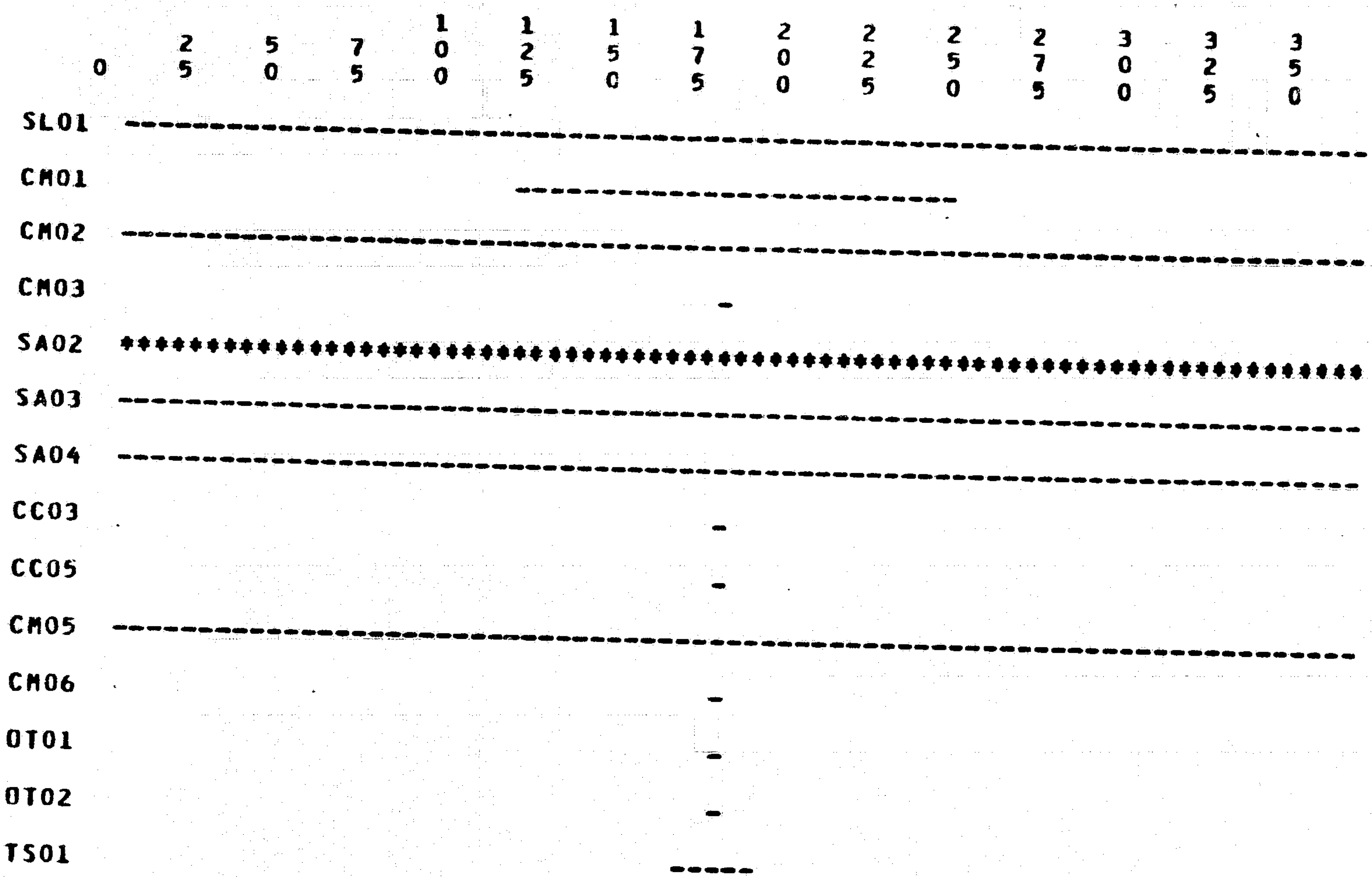
DAYS/YEAR



1996

```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***

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                                 DAYS/YEAR

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      2    5    7    0    2    5    7    0    2    5    7    0    2    5
 0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

OT03                                       -

OT04                                       -

SA01   ********************************************************************************
```

1996

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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: @ NONE: - INERTIAL: *

DAYS/YEAR

```
                      1   1   1   1   2   2   2   2   3   3   3
          2   5   7   0   2   5   7   0   2   5   7   0   2   5        1997
      0   5   0   5   0   5   0   5   0   5   0   5   0   5   0

SL01   -----------------------------------------------------------
CM01                      ---------------------
CM02   -----------------------------------------------------------
CM03                               -
CM04                               -
SA02   ***********************************************************
SA03   -----------------------------------------------------------
SA04   -----------------------------------------------------------
CC03                               -
CC04                               -
CC05                               -
CM05   -----------------------------------------------------------
CM06                               -
OT01                               -
OT02                               -
TC01                        ---------------
TS01                             -----
```

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```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***
     EARTH: ●                    NONE: -                 INERTIAL: *
                                        DAYS/YEAR
                                                                                    1997
                         1    1    1    1    2    2    2    2    3    3    3
          2    5    7    0    2    5    7    0    2    5    7    0    2    5
     0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
S004 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
0T03                                      -
0T04                                      -
SP02 ●●●●●●●
SA01  *************************************************************************
```

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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION

```
EARTH: @               NONE: -                INERTIAL: *
                              DAYS/YEAR                                 1998

                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
SL01  -------------------------------------------------------------------------
CM01                              ---------------------------
CM02  -------------------------------------------------------------------------
CM03                                    -
CM04                                    -
SA02  *************************************************************************
SA04  -------------------------------------------------------------------------
CC03                                    -
CC04                                    -
CC05                                    -
CM05  -------------------------------------------------------------------------
CM06                                    -
OT01                                    -
OT02                                    -
TS01                                  -----
```

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```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***
   EARTH: ●                 NONE: -                 INERTIAL: *
                                 DAYS/YEAR
                     1    1    1    1    2    2    2    2    3    3    3             1998
      2    5    7    0    2    5    7    0    2    5    7    0    2    5
 0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
S004 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
OT03                                    -
OT04                                    -
SP02 ●●●●●●●
SA01  **************************************************************************
```

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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION

1999

```
EARTH: @                 NONE: -                  INERTIAL: *
                               DAYS/YEAR

                           1    1    1    1    2    2    2    2    3    3    3
            2    5    7    0    2    5    7    0    2    5    7    0    2    5
       0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

SL01    -------------------------------------------------------------------------
CM01                                -------------------------
CM02    -------------------------------------------------------------------------
CM03                                            -
CM04                                            -
SA02    *************************************************************************
SA04    -------------------------------------------------------------------------
CC03                                            -
CC04                                            -
CC05                                            -
CM05    -------------------------------------------------------------------------
CM06                                            -
OT01                                            -
OT02                                            -
OT05                                            -
TS01                                          -----
```

C-5

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```
     ***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***
    EARTH: @                  NONE: -                  INERTIAL: *
                                   DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@

S002 @@

S004 @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@

OT03                                     -

OT04                                     -

SP02 @@@@@@@

SA01 **************************************************************************
```

1999

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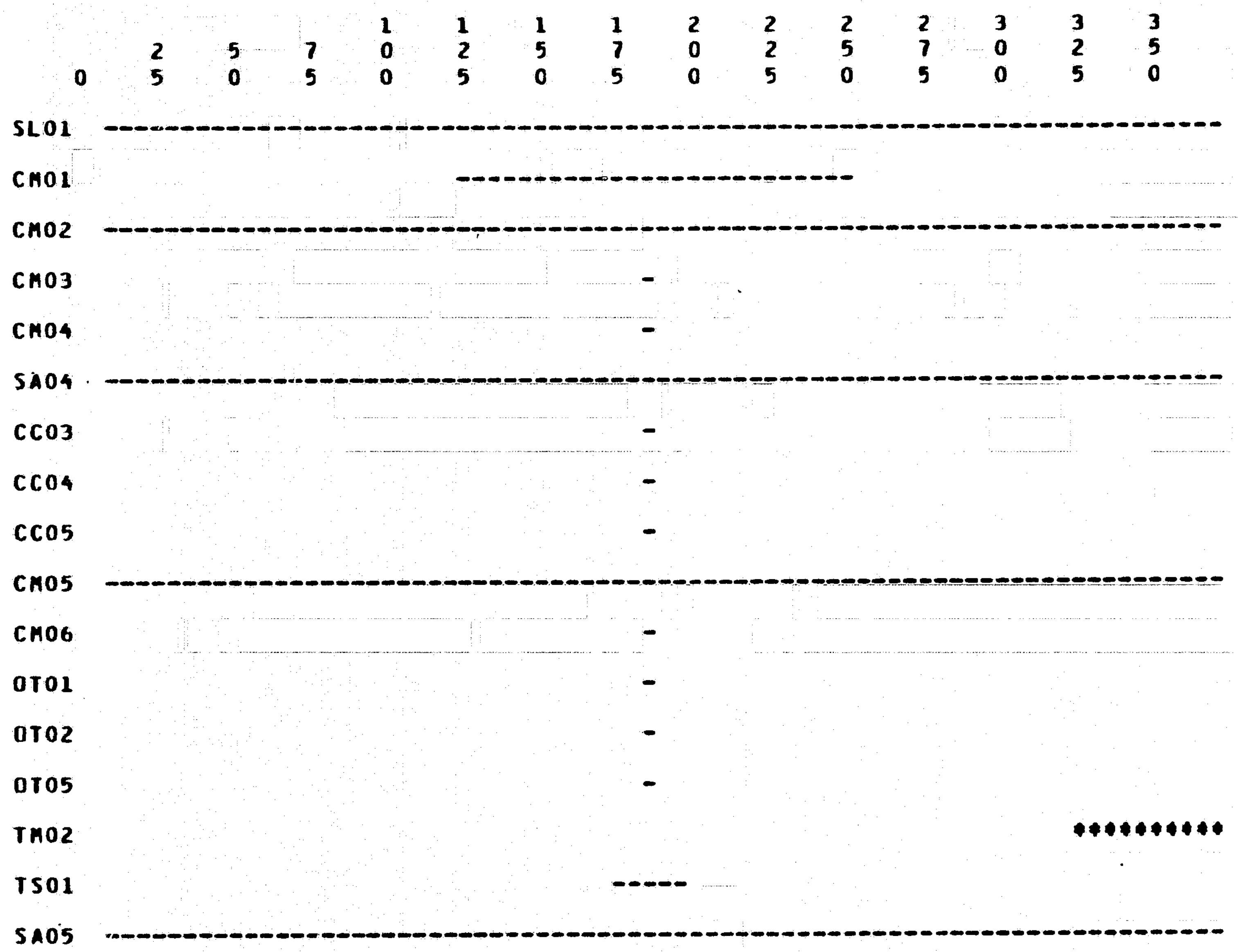
EARTH: @ NONE: - INERTIAL: *

DAYS/YEAR

2000



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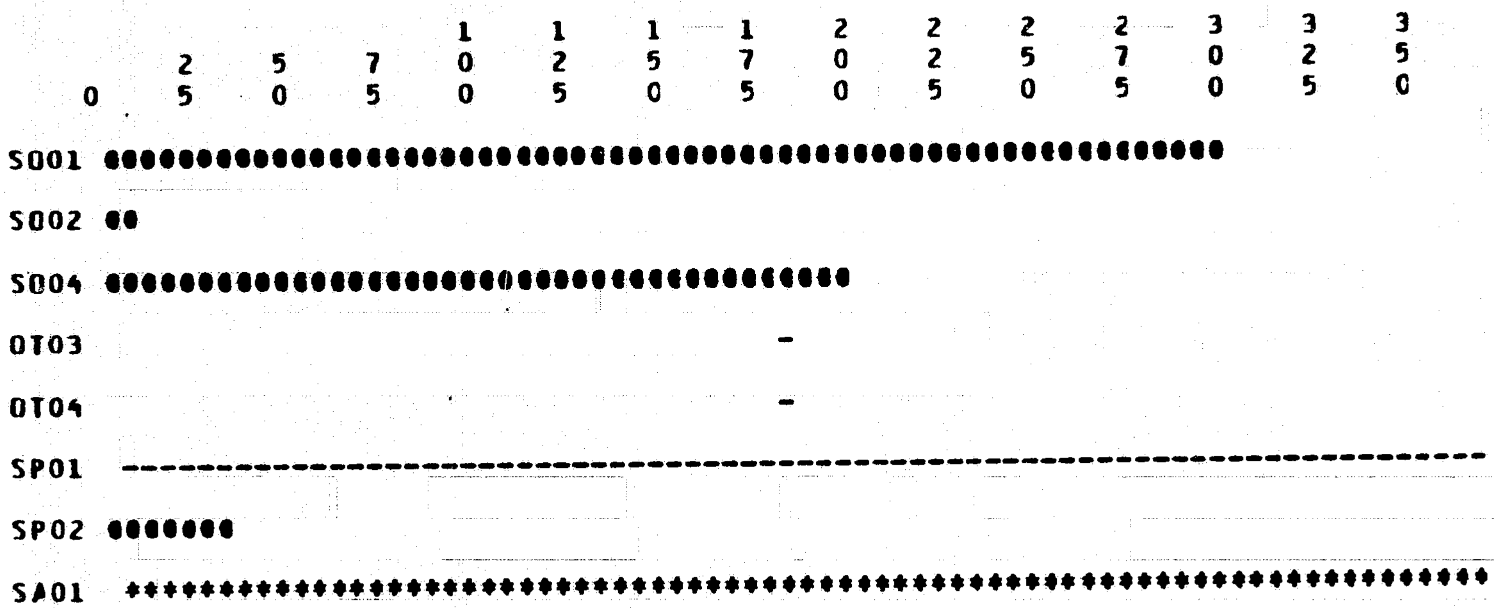
POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

2000



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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION   SPACE STATION

EARTH: @   NONE: -   INERTIAL: *

DAYS/YEAR

2001

```
                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
SL01   --------------------------------------------------------------------------
CM01                          ---------------------------
CM02   --------------------------------------------------------------------------
CM03                                       -
CM04                                       -
SA03   --------------------------------------------------------------------------
SA04   --------------------------------------------------------------------------
CC03                                       -
CC04                                       -
CC05                                       -
CM05   --------------------------------------------------------------------------
CM06                                       -
OT01                                       -
OT02                                       -
OT05                                       -
TS01                                    -----
SA05   --------------------------------------------------------------------------
```

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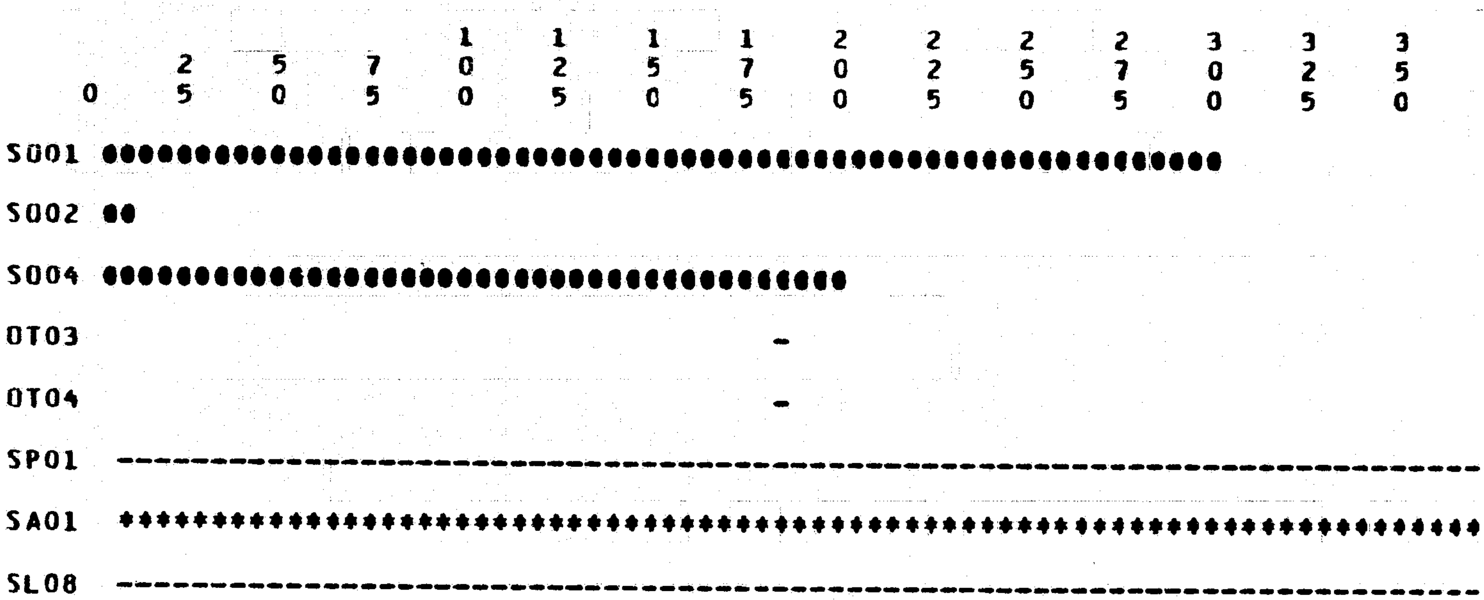
POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR



2001

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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ●   NONE: -   INERTIAL: *

DAYS/YEAR

2002

```
                      1   1   1   1   2   2   2   2   3   3   3
          2   5   7   0   2   5   7   0   2   5   7   0   2   5
      0   5   0   5   0   5   0   5   0   5   0   5   0   5   0
SL01   ----------------------------------------------------------
CM01                       ---------------------
CM02   ----------------------------------------------------------
CM03                                 -
CM04                                 -
SA03   ----------------------------------------------------------
SA04   ----------------------------------------------------------
CC03                                 -
CC04                                 -
CC05                                 -
CM05   ----------------------------------------------------------
CM06                                 -
OT01                                 -
OT02                                 -
OT05                                 -
TM03  ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
TS01                               -----
SA05   ----------------------------------------------------------
```

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POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

```
   EARTH: ●                   NONE: -                INERTIAL: *
                                   DAYS/YEAR                            2002

                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001  ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

S002  ●●

S003  ●●●●●●●●●●

S004  ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OT03                                      -

OT04                                      -

SA01   *************************************************************************

SL08   -------------------------------------------------------------------------
```

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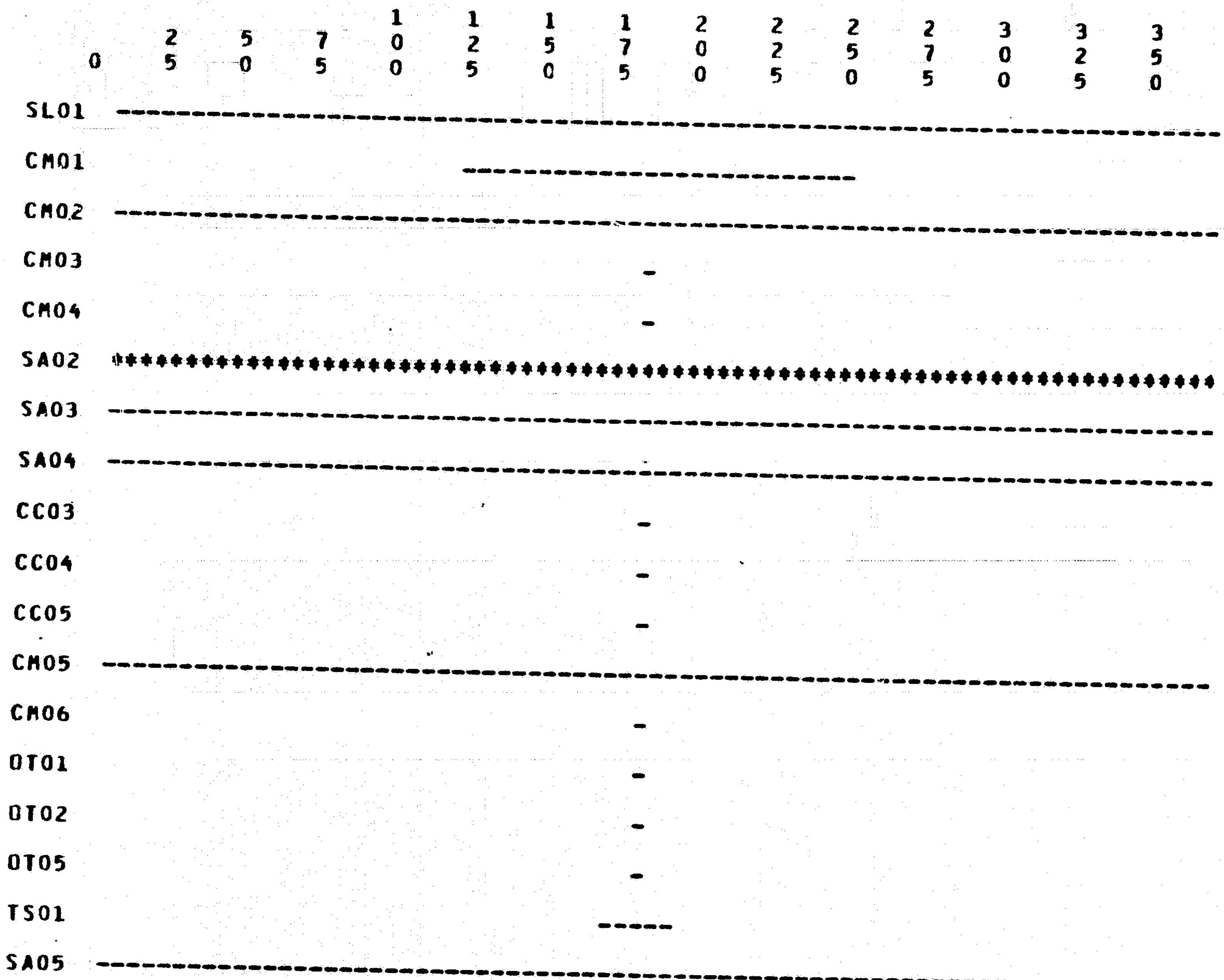
POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

2003



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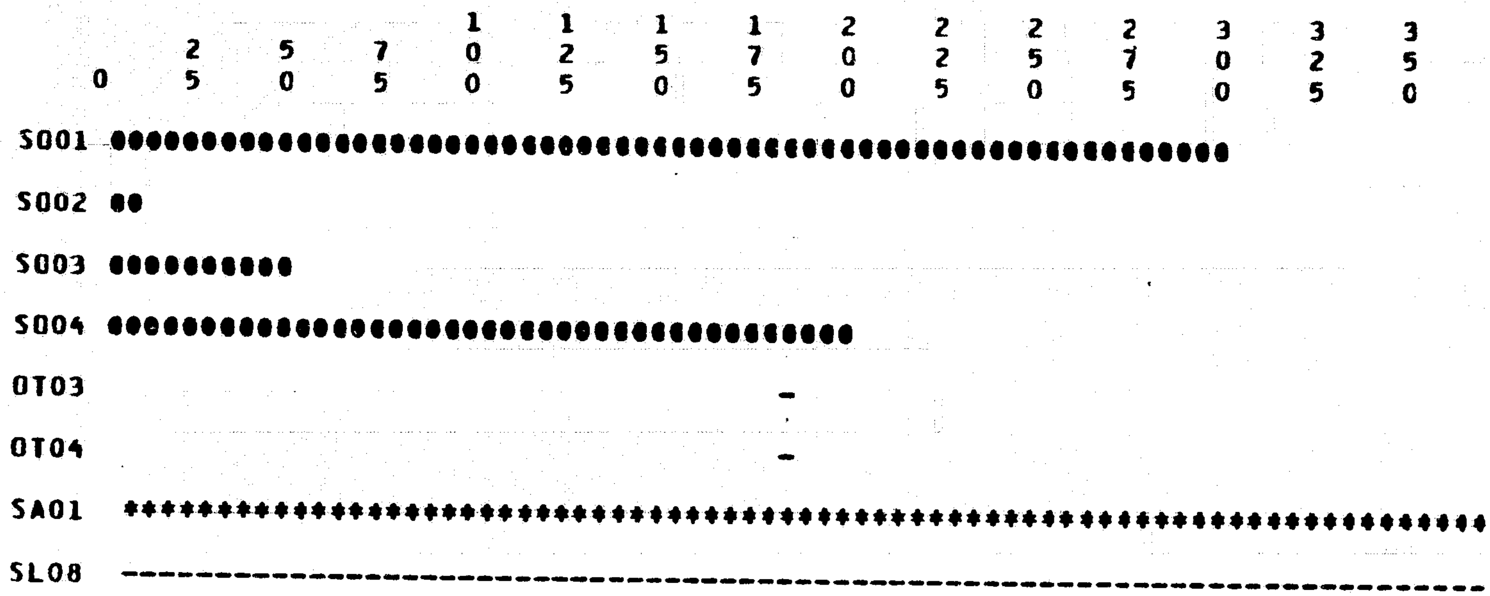
POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION SPACE STATION

EARTH: ●   NONE: -   INERTIAL: *

DAYS/YEAR

2003



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POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: ● NONE: - INERTIAL: *

DAYS/YEAR

2004

```
                          1    1    1    1    2    2    2    2    3    3    3
           2    5    7    0    2    5    7    0    2    5    7    0    2    5
      0    5    0    5    0    5    0    5    0    5    0    5    0    5    0
SL01  -------------------------------------------------------------------------
CM01                              ---------------------------
CM02  -------------------------------------------------------------------------
CM03                                        -
CM04                                        -
SA02  *************************************************************************
SA03  -------------------------------------------------------------------------
SA04  -------------------------------------------------------------------------
CC03                                        -
CC04                                        -
CC05                                        -
CM05  -------------------------------------------------------------------------
CM06                                        -
OT01                                        -
OT02                                        -
OT05                                        -
TS01                                      -----
SA05  -------------------------------------------------------------------------
```

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E-64

```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***

   EARTH: ●                 NONE: -                INERTIAL: *
                                 DAYS/YEAR
                                                                        2004
                         1    1    1    1    2    2    2    2    3    3    3
          2    5    7    0    2    5    7    0    2    5    7    0    2    5
     0    5    0    5    0    5    0    5    0    5    0    5    0    5    0

S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
S002 ●●
S003 ●●●●●●●●●●
S004 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
OT03                                     -
OT04                                     -
SP01 -------------------------------------------------------------------------
SA01 *************************************************************************
SL08 -------------------------------------------------------------------------
```

ORIGINAL PAGE IS
OF POOR QUALITY

POINTING & DISTURBANCE SUMMARY FOR LOW INCLINATION SPACE STATION

EARTH: @   NONE: -   INERTIAL: *

DAYS/YEAR

2005

```
                     1   1   1   1   2   2   2   2   3   3   3
         2   5   7   0   2   5   7   0   2   5   7   0   2   5
     0   5   0   5   0   5   0   5   0   5   0   5   0   5   0
SL01  -----------------------------------------------------------
CM01                     ---------------------
CM02  -----------------------------------------------------------
CM03                                -
CM04                                -
SA02  ***********************************************************
SA03  -----------------------------------------------------------
SA04  -----------------------------------------------------------
CC03                                -
CC04                                -
CC05                                -
CM05  -----------------------------------------------------------
CM06                                -
OT01                                -
OT02                                -
OT05                                -
TE02                                                          ****
TS01                              ----
SA05  -----------------------------------------------------------
```

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```
***POINTING & DISTURBANCE SUMMARY FOR HIGH INCLINATION  SPACE STATION***
   EARTH: ●                     NONE: -                  INERTIAL: *
                                      DAYS/YEAR

                         1    1    1    1    2    2    2    2    3    3    3
         2    5    7    0    2    5    7    0    2    5    7    0    2    5
    0    5    0    5    0    5    C    5    0    5    0    5    0    5    0                    2005

S001 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

S002 ●●

S003 ●●●●●●●●●●

S004 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

OT03                                     -

OT04                                     -

SP01  ----------------------------------------------------------------------------

SA01  ****************************************************************************
```

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